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The Journal of
THE ROYAL AERONAUTICAL SOCIETY

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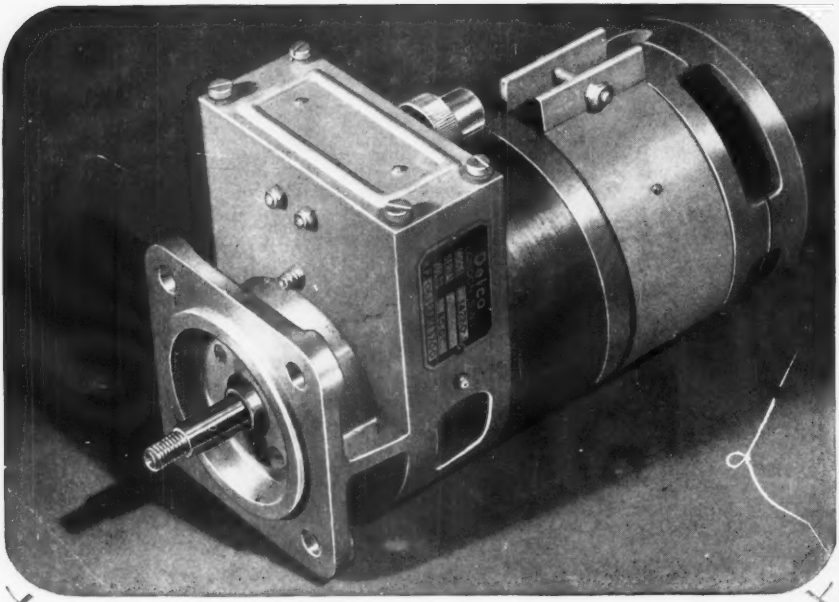

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FEBRUARY NOTICES 1948

JOURNAL PREMIUM AWARDS

The Council have set aside an annual sum of £250 for the award of premiums for papers published in the *Journal* and the Council hope that members (or non-members) will contribute papers on their own special subjects.

CONTENTS OF FEBRUARY JOURNAL

Problems Facing Civil Air Operations, by N. E. Rowe, C.B.E., B.Sc., D.I.C., F.R.Ae.S.

Production of Lift Independently of Incidence—A review of the principles of the Thwaites Flap, the design of suitable aerofoils and some experimental results, by Bryan Thwaites.

Kinematics of Undercarriage Retraction, by H. G. Conway, M.A., F.R.Ae.S.

NEW YEAR'S HONOURS—JANUARY 1948

The following members received awards in the New Year's Honours Lists:—

Knights Batchelor

H. R. Ricardo, F.R.S. (Fellow).
R. V. Southwell, F.R.S. (Fellow).

K.B.E.

Sir Frank Spriggs (Honorary Fellow).

G.B.E. (Military Division)

Air Chief Marshal Sir Guy Garrod (Associate).

C.B.E.

Major F. B. Halford (Fellow).
Mr. F. A. King (Associate Fellow).
Major A. A. Ross (Fellow).

O.B.E.

Mr. R. N. Dorey (Fellow).
Mr. J. P. Jeffcock (Fellow).
Capt. A. G. Store (Associate Fellow).

A.F.C. (Royal Navy)

Lt. Commander S. G. Orr, D.S.C. (Associate).

JOINT AERONAUTICAL CONFERENCE

The complete proceedings of the Joint Aeronautical Conference held from 3rd to 5th September 1947 is expected to be ready in April. The volume, of some 700-800 pages, will contain the 20 British and American papers read at the Conference, together with the discussion on each, and a list of members.

The cost to members of the Conference will be £2 12s. 6d. per volume and to non-members of the Conference, £3 12s. 6d. per volume. A strictly limited number will be printed and orders for the volume should be received by 1st March 1948 at the latest, to save disappointment.

Remittances, payable to Aerial Science Ltd., should be sent with orders.

PRESENTATION OF THE WAKEFIELD GOLD MEDAL

The Wakefield Gold Medal was presented to Mr. Edwin A. Link on 17th December 1947 at the U.S. Chamber of Commerce in Washington, immediately before the Eleventh Wright Brothers Lecture was read by Professor Sydney Goldstein, F.R.Ae.S., to the Institute of the Aeronautical Sciences. The presentation was made by Air Chief Marshal Sir Guy Garrod, K.C.B., O.B.E., M.C., D.F.C., on behalf of the British Ambassador in Washington.

As reported in the Journal for December 1947 (page 947), the medal was formally presented by the President to Mr. L. Satterthwaite, Civil Air Attaché at the American Embassy, on 9th October 1947, as Mr. Link was unable to be present in this country at that time.

EVOLUTION OF THE DESIGN OF AN AEROPLANE, by Professor R. L. Lickley, B.Sc., D.I.C., F.R.Ae.S.—*Summary of Lecture to be given on Thursday, 26th February* 1948.

The paper deals with design processes which take place between the initial conception of a design and the proving flights of the prototype aeroplane.

It considers the effect of the specification on the basic design chosen and discusses the impact of requirements on the project work and throughout the course of the design.

The various stages of completion are examined in relation to their effect on the overall design and the time taken to complete the design.

Possible pitfalls are examined and means of overcoming them described. The effect of office arrangements and duties on the efficient completion is also discussed.

To give substance to the paper a possible specification is gone into in general terms and it is used as a link in this study of the evolution of a design.

In a short conclusion, the possibility of improved training of draughtsmen and technicians is put forward as a means of cutting down design time and eliminating a number of the present troubles. Suggestions as to how this can be done and some mention of the problems to be overcome in this, complete the paper.

FLIGHT TESTING AT HIGH SUBSONIC SPEEDS by H. Davies, B.A., M.Sc., A.F.R.Ae.S.—*Summary of Lecture to be given on Thursday, 18th March* 1948.

A survey will be made of recent developments in flight research at high Mach numbers, with special reference to work done at the Royal Aircraft Establishment.

The methods and technique of flight testing at high speeds will be described in detail and the limitations imposed by inherent difficulties of the work discussed. Refinements in instrumentation needed to cope with high Mach number phenomena will also be discussed.

Flight measurements of compressibility effects on drag, lift, stability and control characteristics and so on, will be analysed, with the aid of pressure distributions, wake-measurements and observations of the flow by means of tufts. The precise origin of the drag rise will be discussed in some detail, with particular reference to scale effects. Considerable emphasis will be placed on comparisons with wind tunnel and other model tests, since it is felt that this constitutes probably the most important aspect of flight research at high speeds. It will be shown that over a wide range of problems existing high speed wind tunnels can give results directly applicable to flight conditions.

Finally, some consideration will be given to future trends in flight research and suggestions made regarding the best methods of dealing with the problems likely to arise.

AIR TRAFFIC CONTROL by Professor A. A. Hall, M.Sc., M.A., F.R.Ae.S.—*Synopsis of the introductory statement to be made by Professsor Hall at the second session (morning) of the All-Day Discussion on "Safety in Civil Aviation" on Saturday, 3rd April* 1948.

The term " Air Traffic Control " embraces the following issues:—

(i) The control of the movement of aircraft on the airport, before take off and after landing.

(ii) The control of the take-off, if necessary in conditions of low visibility.

(iii) The navigation of the aircraft and the maintenance of its schedule.

(iv) The safety of the aircraft from collision with other aircraft, or with obstacles, both en route and when in the vicinity of an airport about which there is a heavy traffic density.

(v) The control of the landing of aircraft if necessary in conditions of low visibility.

Aim

The aim is to produce a combination of technical arrangements which, with due regard for the paramount need for safety, solves the traffic control problem in all its aspects, as set out above, with maximum overall economy.

The Balance of Economy

The following factors are among those which influence the economic balance:—

(i) The capital and running costs of the ground and airborne control equipment.

(ii) The utilisation of aircraft and airports which the system allows.

(iii) The loss of payload caused by the weight of airborne equipment and the weight of fuel which must be carried to allow an aircraft to submit to control (either by delay, by operating at specified height and speed, or by proceeding elsewhere).

The Influence of Aircraft Performance

The control system near an airport aims at securing an ordered arrival pattern by delaying or speeding aircraft in flight. The ability of the aircraft to operate economically over a range of speed and height dictates its flexibility for control. Piston-propelled aircraft are the most flexible; jet-propelled aircraft are extremely inflexible. Present control systems already present difficulties for piston-propelled machines; jet air liners may be doomed economically, until control systems suited to their characteristics are devised.

Principles of Control

Control systems can be classified roughly by the extent to which mandatory authority rests with the captain of the aircraft or with officers on the ground. There is controversy of both an administrative and a technical nature on the desirable and necessary division of authority.

THE PHYSIOLOGICAL ASPECTS OF AIR SAFETY, by Dr. K. G. Bergin, M.A., M.B., A.F.R.Ae.S.

Summary of the introductory statement to be made by Dr. Bergin at the third session (afternoon) of the All-Day Discussion on "Safety in Civil Aviation" on Saturday, 3rd April 1948.

Skilled pre-selection of air crew at the earliest stages of training is a vital matter; unwise or careless selection may result in a breakdown with disastrous results when an emergency arises. Elimination of such personnel, prior to their taking up flying duties, is both economical and conducive to greater safety in the air.

A high standard of day, night and colour vision is essential for flying and accurate hearing is important for communications and interpretation of landing aids. Among other factors which influence night vision adversely are lack of oxygen, alcohol and smoking, while the noises present in flying may result in progressive deafness for which there is no cure; wherever possible, therefore, its onset should be prevented by suitable sound insulation.

The importance of oxygen in flying is now fully established. Lack of oxygen results in deterioration in all forms of judgment and critical faculties. Reaction times are slowed and co-ordination decreased. The effects of alcohol on flying in many ways resemble oxygen lack with a demonstrable lowering of efficiency.

Accurate equilibrium is essential for safe flying, and the main factors responsible for this are vision and a part of the brain called the labyrinth, the latter being responsible for positional awareness and sensations of rotation. A conflict of any of these sensations may lead to grave disorientation with fatal results.

Fatigue in flying requires careful watching, because when a man is fatigued his reaction times are slower, his responses to stimuli less accurate, and he is liable to make errors which he would not otherwise do. Its prevention and cure is a matter of great importance where air safety is concerned.

LECTURE PROGRAMME—1948

The Lectures will be held at 6 p.m. in the Lecture Hall of the Institution of Civil Engineers, Great George Street, S.W.1 (by permission of the Council of the Institution) unless otherwise stated. Tea will be served at 5.30 p.m.

Visitors are welcome, but should obtain tickets through a member of the Society.

Thursday, 12th February 1948—The Aerodynamics of the Gas Turbine, by A. R. Howell.

Thursday, 26th February 1948—The Evolution of the Design of an Aeroplane, by Professor R. L. Lickley, B.Sc., D.I.C., F.R.Ae.S.

Thursday, 18th March 1948—Flight Testing at High Subsonic Speeds, by H. Davies, B.A., M.Sc., A.F.R.Ae.S.

Saturday, 3rd April 1948—FULL DAY DISCUSSION ON SAFETY IN CIVIL AVIATION. Introductory Statements only will be made. Each will be followed by open discussion.

Morning Session

11 a.m.—Air Vice-Marshal D. C. T. Bennett, C.B., D.S.O., F.R.Ae.S., on The Economics of Safety.

12 noon—Professor A. A. Hall, M.Sc., M.A., F.R.Ae.S., on The Problems of Air Traffic Control.

1-2.30 p.m.—Luncheon Interval. Members and visitors should make their own arrangements for lunch.

Afternoon Session

2.30 p.m.—K. G. Bergin, M.A., M.D., M.B., B.Chir., M.R.C.S., L.R.C.P., A.F.R.Ae.S., on Physiological Aspects of Safety.

3.30 p.m.—General Discussion.

4.30-5 p.m.—Tea interval (tea provided).

Evening Session

5-6.30 p.m.—General Discussion and summing-up.

Thursday, 15th April 1948—The Aerodynamic Problems of High Altitude Design, by W. E. W. Petter, B.A., F.R.Ae.S.

Thursday, 27th May 1948—The 36th Wilbur Wright Memorial Lecture will be read by A. Gouge, B.Sc., F.R.Ae.S.

BELFAST BRANCH

Tuesday, 24th February 1948—Evening of lecturettes.

Tuesday, 16th March 1948—Inside Occupied Japan, William Courtenay, M.M., A.R.Ae.S.

All meetings are held at the Assembly Hall, Belfast College of Technology, at 7.30 p.m.

BRISTOL BRANCH

Wednesday, 11th February 1948—The Design of a Large Naval Vessel, by H. S. Pengelley, R.C.N.C., M.Inst.N.A., Assistant Director of Naval Construction, Admiralty.

Monday, 23rd February 1948—Accidents and Their Investigation, by Air Commodore Vernon Brown, C.B., O.B.E., M.A., F.R.Ae.S., Accidents Investigation Branch, Ministry of Civil Aviation.

Wednesday, 3rd March 1948—Reading of Prize-winning Papers by Junior Members.

Monday, 22nd March 1948—Operation of Civil Transport Aircraft, by N. E. Rowe, C.B.E., F.R.Ae.S., Controller of Research and Long Term Development, British European Airways.

Wednesday, 14th April 1948—Film Night and Annual General Meeting.

All meetings will be held in the Conference Room, Bristol Aeroplane Co. Ltd., Filton House, at 6.0 p.m.

GLOUCESTER AND CHELTENHAM BRANCH

Thursday, 4th March 1948—A film, "Castings and Forgings." Introduced by G. F. Ingram—at Gloucester.

Wednesday, 7th April 1948—Annual General Meeting followed by Film—at Cheltenham.

Gloucester meetings are held in the Wheatstone Hall, City Library, Brunswick Road, Gloucester, at 7.30 p.m. on *Thursdays*.

Cheltenham meetings are held in the Chemistry Lecture Theatre, Grammar School, Cheltenham, at 7.30 p.m. on *Wednesdays*.

LUTON BRANCH

Wednesday, 7th April 1948—Rocket Propulsion and Inter-Planetary Flight, by A. V. Cleaver, A.R.Ae.S., at the George Hotel, Luton, at 7 p.m.

MANCHESTER BRANCH

Thursday, 26th February 1948—Naval Aircraft, by Captain Fancourt.

Thursday, 1st April 1948—Flight Refuelling, by C. H. Latimer-Needham.

Meetings will be held at the Reynolds Hall, College of Technology, at 7.30 p.m.

PRESTON BRANCH

Wednesday, 10th March 1948—Bird Flight, by Captain J. L. Pritchard, Hon. F.R.Ae.S. At the Harris Technical College, Preston, at 7.15 p.m.

SOUTHAMPTON BRANCH

Wednesday, 3rd March 1948—A Survey of Fighter Handling Qualities from 1936 to the Present day, by J. K. Quill, O.B.E., A.F.C., Chief Test Pilot, Supermarine Works, Vickers-Armstrongs Ltd.

At University College, Southampton, at 7 p.m.

YEOVIL BRANCH

Thursday, 12th February 1948—The Probable Role and Influence of Aircraft in Future Warfare, by Air Marshal Sir Robert H. M. S. Saundby, K.B.E., C.B., M.C., D.F.C., A.F.C.

Wednesday, 25th February 1948—Helicopter Aerodynamics and Mechanics, by O. L. L. Fitzwilliams, B.A.

Thursday, 11th March 1948—Title to be fixed; P. G. Masefield, M.A.(Eng.), F.R.Ae.S.

Thursday, 25th March 1948—Recent Developments in Flying Boats, by H. Knowles, F.R.Ae.S.

Thursday, 1st April 1948—Annual General Meeting and Film.

Meetings are usually held at the Park School, Prince's Street, Yeovil, at 6.30 p.m.

GRADUATES' AND STUDENTS' SECTION

Wednesday, 25th February 1948—Suction Aerofoils, by B. Thwaites, Department of Aeronautics, Imperial College of Science and Technology.

Wednesday, 14th April 1948—The Influence of the Recent Civil Airworthiness Requirements on Civil Aircraft Design, by W. Tye, B.Sc., F.R.Ae.S., Air Registration Board.

Tuesday, 11th May 1948—The Light Aeroplane and the Future of Private Flying, by P. G. Masefield, M.A., F.R.Ae.S., Director General of Long Term Planning and Projects, Ministry of Civil Aviation.

All meetings will be held in the Library of the Royal Aeronautical Society, 4 Hamilton Place, W.1, at 7.30 p.m.

ASSOCIATE FELLOWSHIP EXAMINATION—MAY 1948

Candidates who wish to take the Associate Fellowship Examination in May should send in their entry forms by 28th February 1948.

ANNUAL SUBSCRIPTIONS OF MEMBERS

Members are reminded that their annual subscriptions became due on 1st January 1948. The present rates are:—

	Home	Abroad
	£ s. d.	£ s. d.
Fellows	5 5 0	4 4 0
Associate Fellows	4 4 0	3 3 0
Associates	*3 3 0	*3 3 0
Graduates (aged 21-25)	2 2 0	2 2 0
Graduates (aged 26-28)	2 12 6	2 12 6
Students (aged under 21)	1 1 0	1 1 0
Students (aged 21 and over)	1 11 6	1 11 6
Companions	3 3 0	3 3 0
Founder Members	2 2 0	2 2 0

* Any Associate elected before 1st October 1947 may, if he wishes, elect not to receive the Journal, and in this case his subscription will be reduced by £1 1s. 0d.

It will avoid delay and confusion when sending remittances for subscriptions if members will state their name clearly and give their address and grade of membership.

CHANGES OF ADDRESS

To assist in keeping the records of members correct and up to date the Secretary will be glad if all members will notify him as soon as possible of changes of address.

When notifying changes please give the following particulars:—

Name (in block letters).
Grade of membership.
New address (in block letters).
Old address.

Changes of address must be received *before the 15th of the month* in order to be effective for the Journal for the following month.

JOURNAL BINDING

Because of increased costs, the prices of binding of Journals will be as follows:—

1947 Volume 15/-.
Previous Volumes 17/-.

Journals should be sent direct to The Lewes Press, Friars Walk, Lewes, Sussex, and the remittance to the Secretary at the office of the Society.

NEW MEMBERS

Associate Fellows

Thomas Edward Garth Bowden (from Graduate), Venkatachalam Cadambe, Richard William Spencer Cheetham, Elmer Coton (from Associate), Kenneth Douglas Drysdale, Charles Fletcher, Arthur Charles Frye (from Student), John Gardiner, Norman Grosvenor Garner (from Associate), Ernest Lawrence Harris (from Associate), Norman Alexander John Harry (from Graduate), Maurice Hermiston, Douglas Gilbert Hitchcock (from Graduate), Subramania Ramamritham, George Ingram Robinson, David John Saunders (from Graduate), John Henry Shelley.

Associates

John Edgar Boyden, William James Hall, Geoffrey Dimmock Nicoll, Francis Eustace Edmund Truscott, George Albert Willis.

Graduates

Stanley Butler (from Student), John Cecil Gibbings (from Student), Geoffrey Bransom Griffiths (from Student), George Ian Livingston Gunn (from Student), Derek George Harris, John Anthony Hay (from Student), Alfred Hucknall (from Student), Robert Frank Harry Kriebel, Milton Lalas, Joseph Stanley Linton, William Maurice Locke (from Student), Jack Harry London (from Student), Peter Ronald McFarlane (from Student), Gilbert McIntosh, John Brian Maw, Peter Edward Thomas Oakley (from Student), Donald William Bernard Owers, Colin Charles Parsons (from Student), Anthoney Mervin Peduzzi (from Student), Colin Walter Rhodes (from Student), Robert Welch (from Student), Michael George Wilde (from Student).

Students

Alan Frederick Constantine, Bruce Kerrill De Rouffignac, Kenneth Thomas Fulton, David Francis Hoare, Christopher Huggins, Murray Alleyn Lowry, Harry Hartley Malley, Richard Dennis William Miller, John Evan Mitchell. Philip Owen, Derek Herrington Peckham, Anthony Lester Pendleton, Sven Thomas Röed, Peter Travers Ross, John Tudor, Ronald Charles Wakeford, Edward Wood.

ADDITIONS TO THE LIBRARY

Pamphlets in italics with location reference following in brackets. Books marked * or ** may not be taken out on loan.

A.a.339—Technical Aerodynamics. Karl D Wood. McGraw Hill. 1947.

B.c.76—Gliding and Advanced Soaring. A. C. Douglas. Murray. 1947.

*E.f.113—Instruction Book. Maintenance and Repair, Airspeed Consul. Airspeed Limited.

*E.f.114—Dragon Rapide Mks. II and III. Care and Maintenance Manual. De Havilland Aircraft Co.

G.e.K.12—Requirements and properties of adhesives for wood. R. A. C. Knight. D.S.I.R. Forest Products Research Bulletin No. 20. H.M.S.O. 1946.

L.d.116—*Notices to Airmen. Nos.* 358, 359, 360, 361, 362, 363, 364, 365, 366, 367, 368, 369, 370, 371, 372, 373, 374, 375.

L.d.121—Applied D.R. Navigation and Flight Planning. J. H. Clough-Smith. Pitman. 1947.

L.d.122—Radio Aids to Navigation. R. A. Smith. Cambridge University Press. 1947.

L.d.123—*Notices to Airmen. Nos.* 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 14, 16.

N.A.C.A. Technical Notes

1487—*Effect of aspect ratio and taper on the pressure drag at supersonic speeds of unswept wings at zero lift. Jack N. Nielson.*

1490—*Comparative performance of two vaneless diffusers designed with different rates of passage curvatures for mixed-flow impellers. Frank J. Baring.*

1380—*The* 1350 *degrees stress-rupture properties of two wrought alloys and three cast alloys. E. E. Reynolds, J. W. Freeman and A. E. White.*

1385—*Stress-strain and elongation graphs for alclad aluminium-alloy* 76S-*T sheet. J. A. Miller.*

J. LAURENCE PRITCHARD,
Secretary.

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MAR 3 '48

The Royal Aeronautical Society

ACTIVITIES OF THE GRADUATES AND STUDENTS SECTION

February 1948

The Section Committee has elected Mr. J. W. F. Housego, Grad.R.Ae.S., to be Chairman of the Section for the remainder of the Session in place of Mr. R. J. Ross, who has resigned on leaving the London area.

Included in the Section's meetings this month is a lecture on 25th February to be given by Mr. Thwaites, of the Imperial College of Science and Technology, London. Mr. Thwaites will lecture on " Principles of Boundary Layer Control " and their application to suction aerofoils.

The attention of members is drawn to the Section's Annual General Meeting, which will be held in April. At this meeting members have an opportunity to make suggestions regarding the management of the Section and to decide its future policy.

A new committee is also elected at the Annual General Meeting and holds office for one year. This committee should be as representative as possible of firms and colleges within reach of London. It is hoped, therefore, that Graduates and Students at firms and colleges not at present represented on the Section Committee, will nominate one or more of their number between now and April to serve on next year's committee.

Lecture

The following is a summary of a lecture on "Aircraft Design from the Airline Point of View" by Mr. Christopher Dykes, Deputy Chief Project Engineer to the British Overseas Airways Corporation, held in the Library of the Society on 12th December 1947.

M. Dykes' lecture was divided into the following parts:—

1. General Requirements.

There were many different routes and purposes for which an aircraft was needed and the requirements had to be studied in each particular case, in order to obtain the best aircraft design.

Flying boats, although they possessed advantages such as superior safety and comfort, were more expensive to operate than landplanes. This was because of higher station costs, resulting from the small use of flying boats by other airlines.

2. Capacity and Layout.

Seating arrangement largely controlled fuselage dimensions. Suggested widths for seats were 24 inches, gangway widths 15 inches in small aircraft, and 24 inches in aircraft carrying stewards. Headroom should be 7 ft. The normal seat spacing was 39 inches, but this was being increased to 45-48 inches on tropical routes, and to 60 inches for long-range luxury aircraft.

The optimum method of conversion from seats to bunks replaced eight seats by six bunks, the seats being arranged three abreast on one side of the gangway with a single seat on the other side. Bunks were expensive (approximately 25 per cent. additional on the fare), and their need would be reduced on many routes by faster flying speeds.

The lecturer recommended that galleys should be located centrally to avoid carrying all the food past one group of passengers.

Luggage compartments should be easily accessible and conveniently shaped. An adaption of the Plimsoll Line in cargo holds was used to control the density loading of bullion.

Racks should be provided for handbags in ladies' toilets, and adequate space for hanging coats was also essential. Gangway and underseat carpet should be of contrasting shades to avoid the matching occasioned by uneven wear.

This section of the lecture was illustrated by numerous slides showing typical layouts in British, American and Canadian aircraft.

3. Speed.

Operating speeds were governed by several considerations such as suitable departure and arrival times, the number of aircraft operated, service and maintenance facilities, and length of flight. A journey time of over ten hours justified the provision of bunks and entailed the carrying of a relief crew.

From these factors it had been estimated that a speed of 550 m.p.h. on the Atlantic route would avoid the need for bunks and permit an aircraft to make the return journey within a period of 24 hours.

4. Range and Payload.

The operator's main interest was the payload which could be carried over any given range. Severe limitations were often imposed on the payload-range relationship by such factors as landing weight, maximum load, and volumetric restrictions.

Payload was reduced as the flight stage increased, by the need to provide more food and comfort for passengers and the total weight of items such as seats, furnishings, food and so on, might be as high as 535 lb./passenger on long stages.

Estimates of operating costs depended on performance figures supplied by the manufacturers and the lecturer made a plea for greater accuracy in this respect.

5. Engineering.

The foremost requirement was safety, with maintenance a second consideration. Fire was a great hazard and detectors should be placed wherever there was a possibility of fire. Hydraulic lines should not be placed near electric cables as the fluid might leak and cause a fire. Foolproof controls (*i.e.* to prevent aileron control reversal and so on), nose-wheel undercarriage (for ease of taxying and loading), ample inspection panels and oxygen apparatus, were all desirable features.

Maintenance was an important consideration since it accounted for one-third of the direct operating costs. Utilisation of aircraft was also dependant on maintenance.

After the lecture Mr. Dykes replied to a number of questions dealing with pressurisation, rearward facing seats, and so on.

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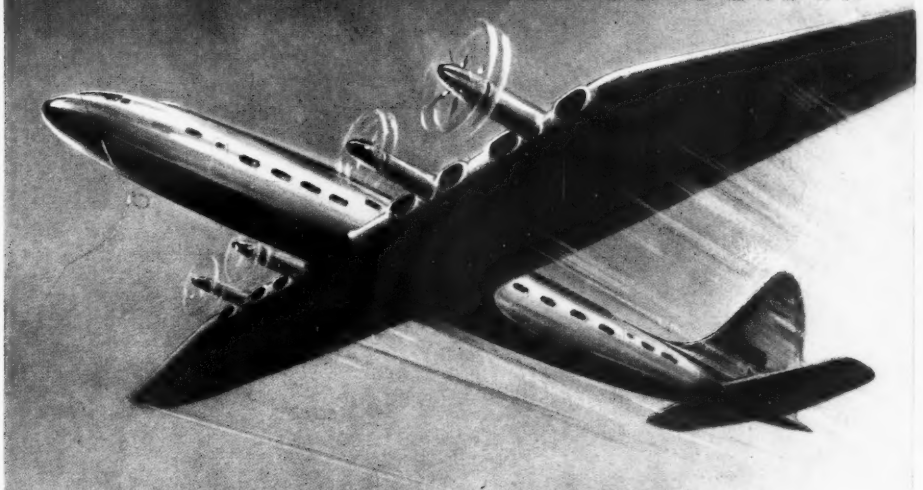

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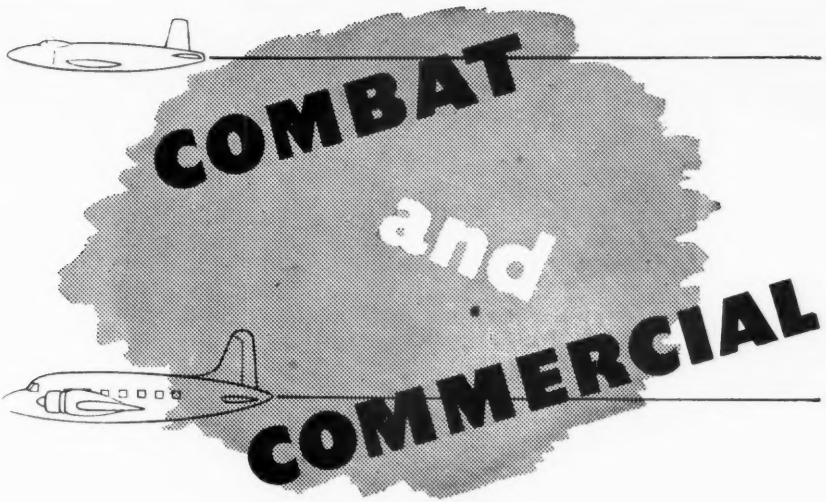

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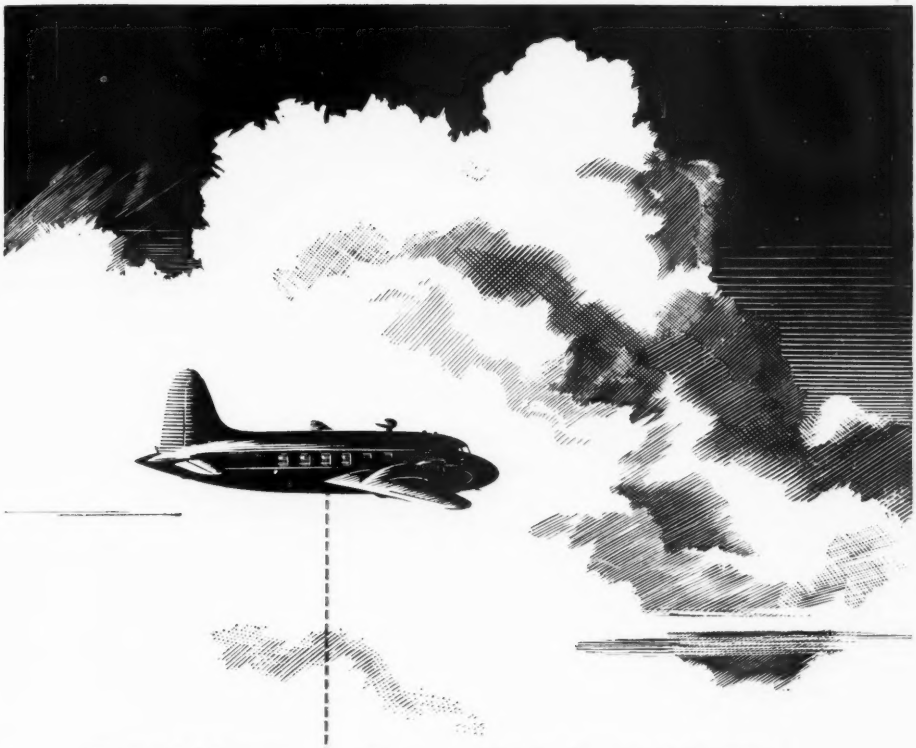

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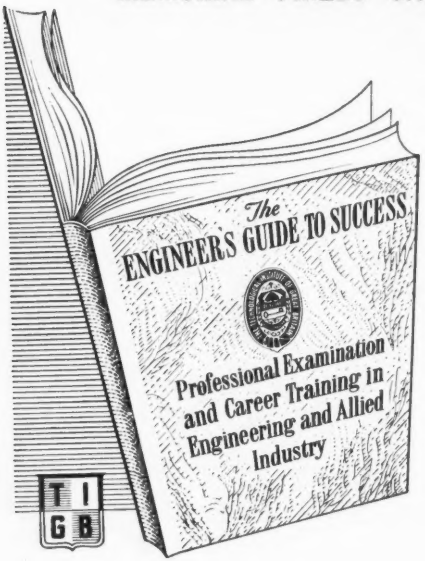

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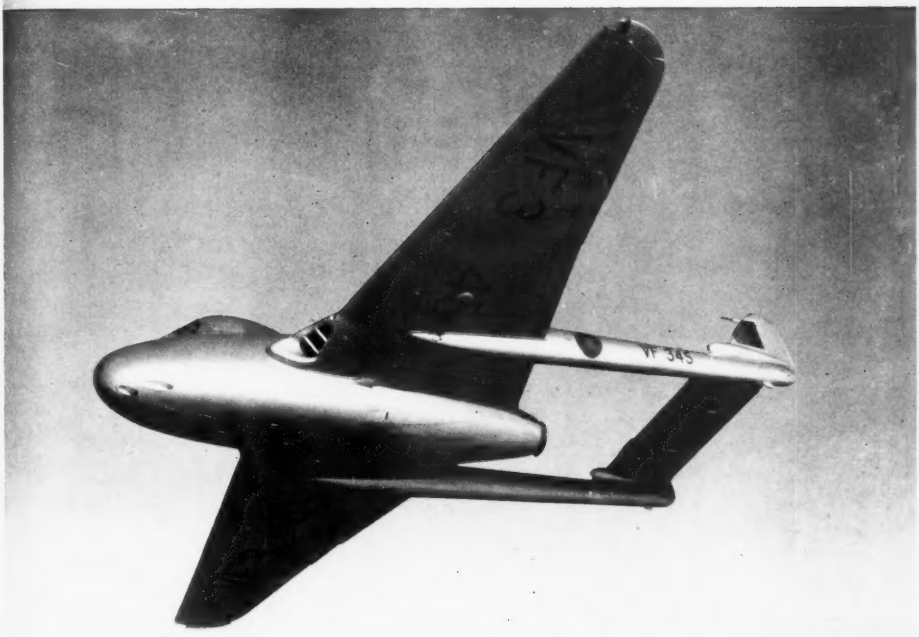

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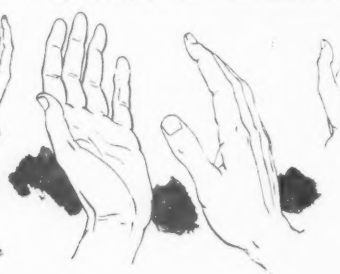

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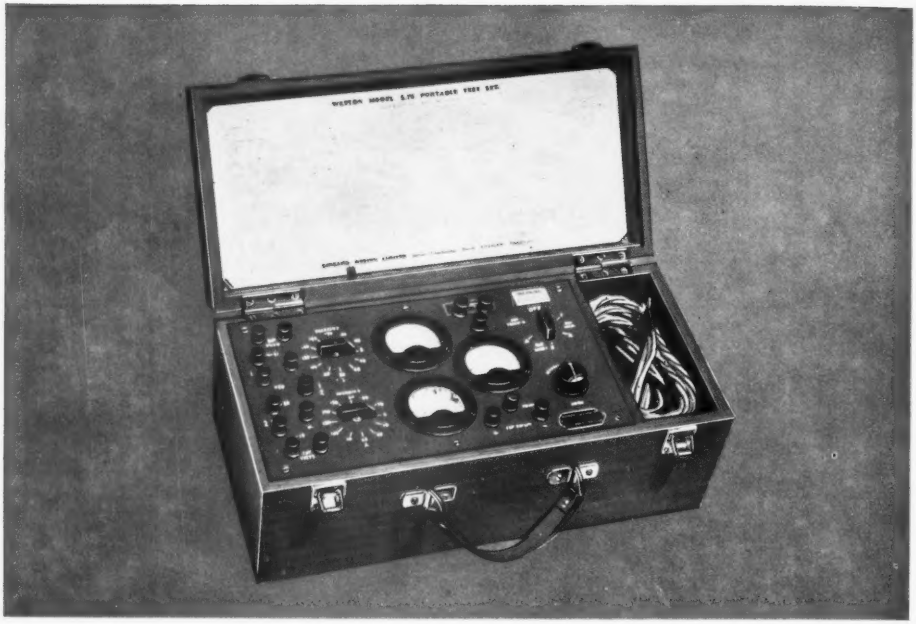

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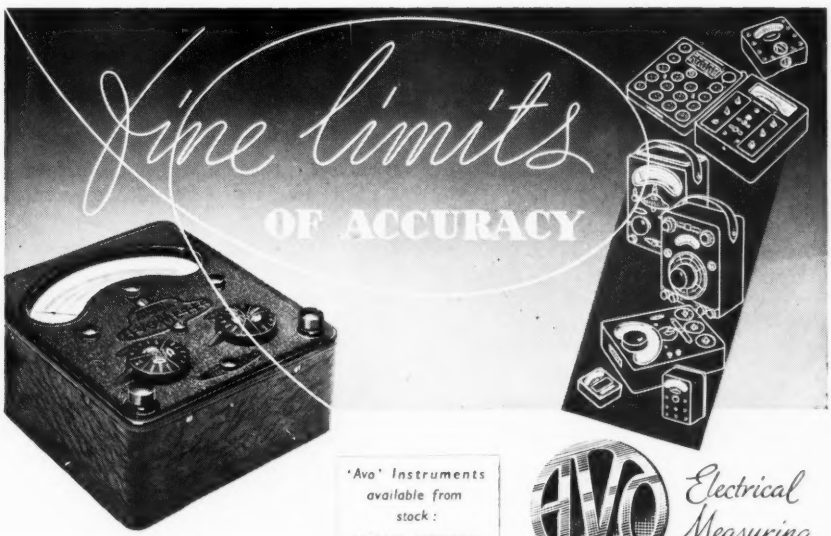

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Society's Gold Medal

Conferred for work of an outstanding or fundamental nature in aeronautics.

British Gold Medal for Aeronautics

Awarded for an achievement leading to advancement in aeronautical science.

Simms Gold Medal

Awarded for the best paper read in any year before the Society on any science allied to aeronautics, *e.g.*, meteorology, wireless telegraphy, instruments.

The George Taylor (of Australia) Gold Medal

Awarded for the most valuable paper submitted or read during the previous session.

Wakefield Gold Medal

Awarded to the designer of any invention or apparatus tending towards safety in flying; open to members or non-members.

Society's Silver Medal

Awarded for some advance in aeronautical design.

British Silver Medal for Aeronautics

Awarded for an achievement leading to advancement in aeronautical science.

Society's Bronze Medal

Awarded under the same conditions as those for the Silver Medal, but for some less important advance in aeronautical design.

Wilbur Wright Memorial Premium

The Wilbur Wright Memorial Lecture is held annually, a premium of £75 being awarded to the lecturer invited by the Council to deliver the lecture. The lecture is usually given alternately by an American and and Englishman, and is the most important aeronautical lecture of the year.

British Commonwealth and Empire Lecture

The British Commonwealth and Empire Lecture is delivered annually by a lecturer chosen in alternate years from the British Dominions and Colonies and Great Britain.

The British Commonwealth and Empire Lecture has a premium of £50 attached to it, and in the case of lecturers coming from the Dominions and Colonies an allowance will be paid towards the Lecturer's expenses.

R.38 Memorial Prize

Offered annually for the best paper received by the Society on some subject of a technical nature in the science of aeronautics, preference being given to papers which relate to airships. The prize is twenty-five guineas.

The Herbert Akroyd Stuart Lectures

Under the will of the late Mr. Herbert Akroyd Stuart a sum of £700 is held in trust by the Society for the offer of a prize every two years, for the best paper or lecture read or given before the Society dealing with the Origin and Development of Heavy-oil Aero-Engines. The prize is open to members and non-members.

Edward Busk Memorial Prize

Offered annually for the best paper received by the Society on some subject of a technical nature in connection with aeroplanes (including seaplanes). Its value is twenty guineas.

Pilcher Memorial Prize

Offered annually for the best paper by a Student on heavier-than-air craft or any analogous subject. Its value is five guineas.

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Offered annually for the best paper by a Student on some subject in connection with Aero-Engines. Its value is five pounds.

Major Baden-Powell Memorial Prize

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Awarded twice yearly to the apprentice at Halton who has the highest percentage of marks in the passing-out examination. Its value is two and a half guineas for each award.

R. P. Alston Memorial Prize

Awarded to any Graduate or Student of the Society for work done leading to improvement in the safety of aircraft, and particularly for improvement in stability and control. Its value is approximately five pounds.

Branch Prize

The Council offers an annual prize of twenty guineas for the best paper read before the Branches during the previous lecture Session. The prize is open to any member of the Society or of any Branch.

Journal Premium Awards

The Council has set aside an annual sum of £250 to be given as premium awards to authors of papers published in the JOURNAL.

THE ROYAL AERONAUTICAL SOCIETY

The 742nd paper read before the Society—on 4th December 1947 at the Institution of Civil Engineers, Great George Street, London, S.W.1. In the Chair, the President, Dr. H. Roxbee Cox, D.I.C., F.R.Ae.S.

PROBLEMS FACING CIVIL AIR OPERATIONS

by

N. E. ROWE, C.B.E., B.Sc., D.I.C., F.R.Ae.S.

Mr. Rowe took his degree at the City and Guilds Engineering College (Royal Scholarship) and joined the Royal Aircraft Establishment at Farnborough in 1924. *From* 1926 *to* 1929 *he was Technical Officer at Martlesham Heath and for the next eight years served at Farnborough and the Air Ministry, returning to Martlesham Heath in* 1937 *as Chief Technical Officer. In* 1938 *he was appointed Assistant Director, Department of Technical Development, Air Ministry and in* 1941 *Director of Technical Development, Ministry of Aircraft Production, becoming Director-General in* 1945. *Since* 1946 *he has been Controller of Research and Long-Term Development of the British European Airways Corporation. He is a Vice-President of the Society.*

1. SCOPE OF LECTURE.

MY purpose is to try to place before you three broad main problems which cover numbers of subsidiary matters of great significance. Taking safety as read (and safety itself is not a problem but a necessity, begetting various problems in varying circumstances), my divisions of the subject are:—

1. Reliability including regularity.
2. Safety in the context of economy.
3. Economy of operation.

Within these divisions the problems which are before us and to which I shall refer are:

1. *Reliability*:

   Precise navigation in all meteorological conditions. Approach, landing and take-off in "blind" conditions. Aircraft flying qualities.

2. *Safety with economy*:

   Air traffic control. Operators' problems. Design problems. Crew fatigue.

3. *Economy of operation*:

   Definition of future requirements. Forecasting traffic. Development of new types of aircraft. Maintenance.

As the lecture proceeds you may complain that operations and operators tend to get mixed in my presentation of the problems, but I offer no apologies bearing in mind that the work of the operator lies in operations.

2. FUTURE—GENERAL COMMENT.

The implication of the title is that one should treat mainly of immediate problems, but I do not think it was so intended; it would most certainly be restrictive and, so far as our own experience in this country is concerned, because of the aftermath of the war, it would not be representative of civil air operation generally. Hence, I intend to say something of the long term as well as of the short term problems, which at once leads to some consideration of what the future holds. There can be no doubt of the further growth of transport by air both of passengers and cargo, and especially of the latter. Figs. 1,

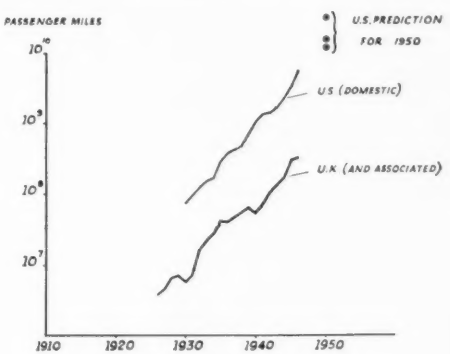

Fig. 1
Growth of passenger miles in U.K. and U.S.

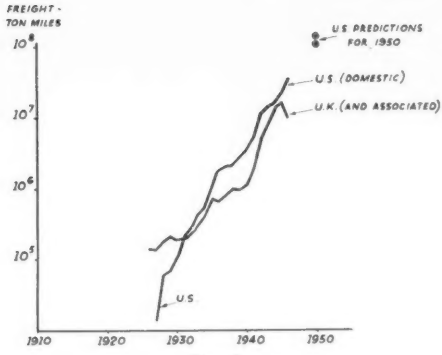

Fig. 2.

Growth of air-freight (ton-miles) (not including mail).

2 and 3 show what has been achieved during the past 20 years. What is most significant is that the *rate* of increase of traffic is showing no signs of slackening.

The nature of the problems which this growth will bring, depends on many factors which probably would be given varying emphasis by different people. My own guess is that operating speeds, and hence frequencies, will steadily increase giving rise to major air traffic control and airport problems; that the drive for economy will be greatly intensified, forcing designers as well as operators to new solutions of existing problems; that cargo operation will advance rapidly and take on a specialised nature with reactions on operating organisation, design and airports; that we are likely to see a steady growth in helicopter operations at short stages. It is important that the assessment of the longer term should be reasonably

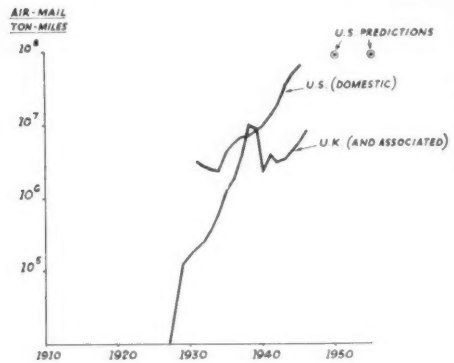

Fig. 3.

Growth of air mail.

correct, since otherwise solutions of short term problems may be merely palliatives instead of the early stages of the answers to the long term problems. And one cannot assess one's problems without giving some thought to their possible solution.

3. OPERATOR AND OPERATIONS.

The air operator is selling a service which he must make as attractive as he can, while still making a reasonable profit. Fundamental factors in his business are the route system he has to operate, the traffic he expects to carry and the aircraft he chooses, or can buy, for his operations. So far as it lies within his power to do so, he must ensure a safe operation by his organisation, his methods, his choice and training of staff. Much of the ultimate responsibility for safety lies without his competence, coming within the field of the designers, regulatory authorities and airport owners. In civil air operation, safety can be taken as a *sine qua non;* all concerned are agreed on its necessity. It merits close examination when considering overall economy, and I shall refer to it again later in this context.

4. PROBLEM 1—RELIABILITY AND REGULARITY.

A major criticism of air transport to-day is its unreliability; clearly, then, this is also a major problem of airline operations. By unreliability, I do not mean susceptibility to accident, although accidents may be a source of unreliability; I mean an uncertainty that a scheduled operation will be completed according to plan under all conditions of weather or operational mischance. Europe is a particularly bad area for weather difficulty, but unreliability is by no means confined to this part of the world. "If you've time to spare, go by air" has been a saying in the U.S.A. for some years and roughly epitomises the situation. Operators will never give good service and attract full potential traffic until this situation is greatly improved.

4.1. STANDARD OF RELIABILITY.

What is an acceptable standard for year-round working? Incidence of zero/zero weather gives a clue to the answer at this stage of development of navigational aids to landing and take-off. Fig. 4 shows the average frequency of such conditions at five airports in N.W. Europe defined as cloud base below 150 ft. or visibility less than 55

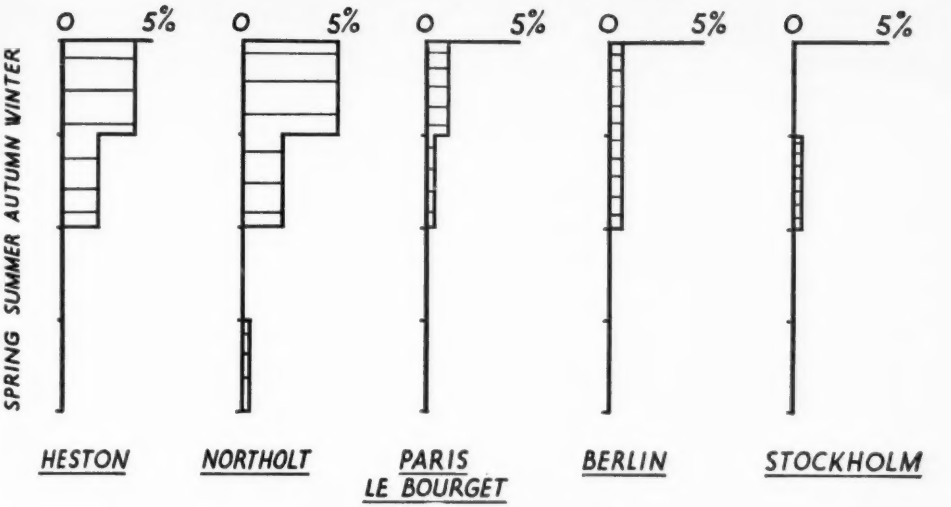

Fig. 4.
Frequency of zero/zero conditions in N.W. Europe.

yards. The average frequency of the five major airports in the U.S.A. which have the highest proportion of "closed" weather is 4 per cent. This is not necessarily zero/zero, but weather below the standard minima for instrument conditions, *i.e.* cloud ceiling less than 500 ft. and visibility less than one mile in U.S.A.

The effect on operations of this bad weather in Europe is shown in Fig. 5 of cancellations of B.E.A. continental services because of weather during the twelve months ending September 1947. The average for the

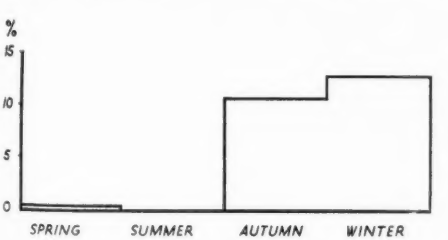

Fig. 5.
Average cancellations in B.E.A. Continental Services for October 1946 to September 1947 (due to weather).

period is 5.4 per cent. The average of the ratio scheduled miles flown to miles scheduled for four major airlines in the U.S. for the 12 months ended June 1947 and June 1946 is 94.8 per cent. and 95.6 per cent. respectively; these figures are not strictly comparative as they may include irregularities due to causes other than weather. But they show what has been achieved in well-established conditions of operation at this time and the need for improvement.

Assuming that the irregularities occur mainly in the bad weather seasons, then a standard or target of not less than 98 per cent. regularity would seem to be reasonable. The main causes of cancellations are weather and unserviceability because of mechanical failure. It is clear from the data shown in Fig. 4 that the latter must be eliminated if we are to achieve the standard in N.W. Europe. This is a problem of design and maintenance and calls for energetic action by all concerned. A palliative is to hold more aircraft in reserve, but this is most uneconomical and increases the chances of failure.

In assessing reliability one must not forget the importance of punctuality, especially to the business passenger over the short stage flights.

During the twelve months ended July 1947, 8.9 per cent of arrivals in B.E.A. Continental Division were over two hours late; the great proportion because of weather. This compares with data for express trains in this country given in Hansard recently as 4.5 per cent. for the month of September 1947.

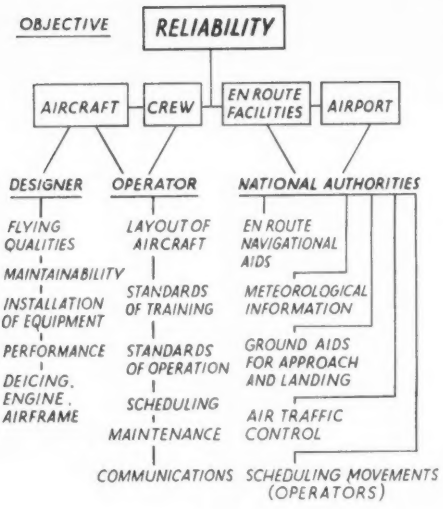

Fig. 6.

4.2. Scheduling of airports for regularity.

In Fig. 6 I have attempted to show the various interests concerned in the objective—reliability. The method of operation of airports is of vital importance, and the biggest factor affecting reliable running is the time difference between operations under clear and low visibility conditions, C.F.R. (Contact Flight Rules) and I.F.R. (Instrument Flight Rules) as they are called. In illustration, I can quote figures for La Guardia (N.Y.) and Washington National Airport, for which I am indebted to Mr. T. P. Wright, Chief Administrator of the C.A.A., in the U.S., given in Fig. 7. For comparison, the theoretical capacity of London Airport in 1953, when it is finally completed, is 160 movements per hour in contact conditions and two-thirds of that in instrument conditions.

It is evident that if aircraft are scheduled into and out of these airports, assuming C.F.R. conditions and I.F.R. conditions supervene, then there will be irregularity which will become widespread and lead to wholesale cancellation if the low visibility weather persists. Hence, a first condition of reliable running must be the scheduling of airports for I.F.R. conditions, unless their frequency of occurrence in any given route system is within the 2 per cent. margin of irregularity in our suggested standard over any given period, when C.F.R. scheduling is permissible. This condition has wide implications for the future:—

(i) Concentration on the problem of reducing the disparity between C.F.R. and I.F.R. movements at airports, involving basic improvements in navigation, air traffic control, ground and airborne equipment.

(ii) Provision of more airports.

(iii) Increase in seating, capacity of aircraft to carry increased traffic within restricted capacities of existing airports.

(iv) Running more traffic at night, especially cargo and, of course, mail.

(v) Rapid and universal adoption of up-to-date equipment, airborne and ground, by all nations engaging in international air transport.

It is of interest that at a very early stage B.E.A. insisted on I.F.R. scheduling at Northolt.

A difficulty arises in Europe in relation to (v) above which is not found to such a marked degree elsewhere. This comes from the multiplicity of national boundaries and interests. Machinery has been set up under I.C.A.O. to obtain agreement on standardisation, but even when this essential prerequisite has been satisfied—and we have not yet got so far—there remains the supply, installation and operation of the equipment. Until all operators and airports have reached the required standard, irregularities will still occur.

4.3. Navigation and reliability.

For maximum utilisation the scheduled airport demands precision in timing of arrivals and departures. This is the fundamental requirement also for punctuality and is a problem of navigation. Hence the primary problem in navigation in this context is precise definition of position in space and time; this ability, when available, to be used to follow a flight plan scheduled throughout the stage, finally matching the schedule of arrivals at the airport. It is claimed that either of two systems is basically suitable for this for *en route* navigation; the American omni-directional range which, in essence, defines traffic lanes, spaced in height and azimuth between zones of air traffic control at the airports of departure and arrival; and the British GEE system which, in essence, defines position by the time difference of signals received in the aircraft from a master

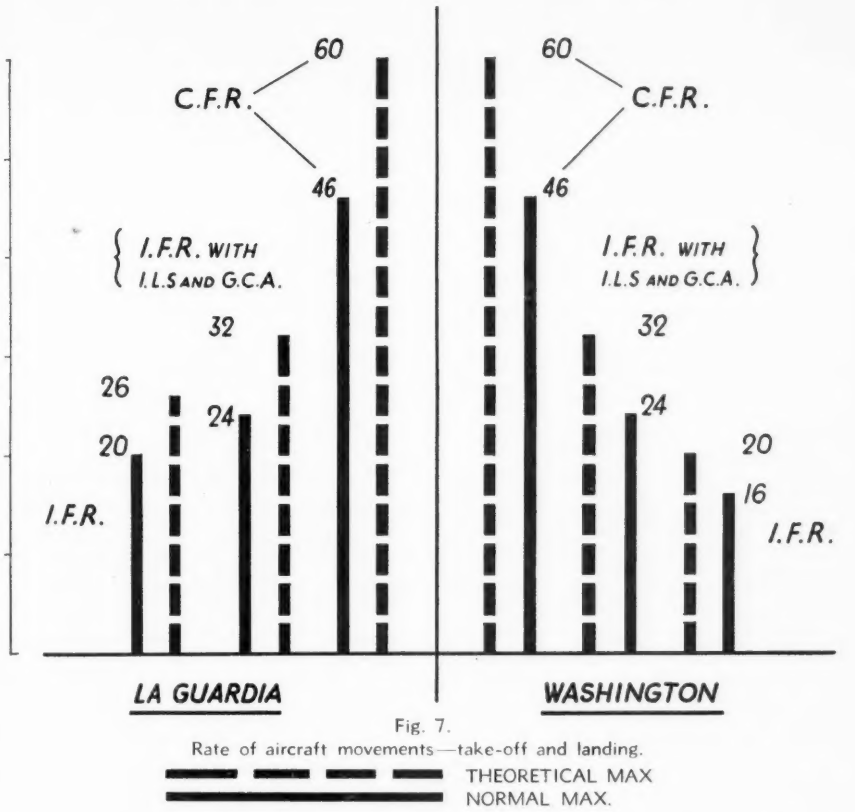

Fig. 7.
Rate of aircraft movements—take-off and landing.

and two or three slave stations emitting pulse radiations. In contradistinction to the American system, it may be called a system of free or individual navigation, between zones of air traffic control at departure and destination. For full navigational facility over an area both systems need some form of distance measuring equipment, dissimilar in the two systems; in neither case is this fully developed.

In both systems aircraft movements are subject to control from the ground within a zone around airports; such control is clearly of great potential importance in its effect on reliability—and indeed on economy—and it is essential that a system shall be evolved which will interfere with traffic movements only to the minimum extent needed to ensure safety. It should, in my opinion, be reduced so far as possible, to a monitoring system only. The operator is vitally concerned in this aspect of development.

Precise navigation must be backed by sufficient flexibility in cruising speed to achieve the flight plan and airport schedules, despite adverse or favourable conditions of weather.

4.4. Blind approach.

The immediately preceding remarks have tended to emphasise the problems of ensuring punctuality. This is an important, but perhaps minor, factor in the problem of reliability of civil air transport under European winter conditions. Last winter, between the months of October 1946 and March 1947 inclusive, over 11 per cent. of B.E.A. Continental services were cancelled because of weather. Fig. 5 shows the incidence of this unreliability. Last winter was a bad one but air transport must be able to take the good with the bad if it is ever going to play its full part and fulfil its great mission. The immediate problem then is to

operate at all throughout a European winter; here the causes are meteorological—fog, low visibility, snow, icing—and the full cure resides mainly in the factors on the right of Fig. 6, previously shown.

At this stage it is necessary to show how the problem is influenced by a proper discrimination between the blind approach followed by a visual touch-down and the blind approach followed by a blind landing. The crucial point is the minimum standard of visibility required by a pilot to ensure a safe landing after the blind approach. Pilots differ in their opinions on this point, but taking horizontal visibility of 500 yards, and a cloud ceiling of 150 ft., we can see from Fig. 8 (Incidence of low visibility conditions at Northolt) that a solution to the blind approach problem will eliminate at least 50 per cent. of existing cancellations out of Northolt. Weather data for Heston, which represents London Airport reasonably well, shows a similar improvement to be possible.

The nature of the problem is familiar to us; it is to give precise definition to a linear flight path from an approach "gate" to a point on the centre line of the runway. A reasonable solution is to hand in the Instrument Landing System; it was described in principle in H. F. Pritchard's lecture to the Society in October 1946 and has been adopted as the International Standard Blind Approach System. It may not be a final solution since the path is quite badly distorted by interference of ground and buildings at some airfields. It is not yet installed in any British aircraft or in any operating on the European route system, and is unlikely to be brought into general use over here for three or four years. As a palliative the Standard Beam Approach System is being used in B.E.A. No blind approach system can have its full value in ensuring regularity unless operating crews are constantly practised in it. This means that the approach, in all weathers, clear and murky, should be made by instrumental means. When the need comes, crews then make the approach with sureness and confidence. This, then, is a matter for operators in training and standards of operation.

4.5. Operation in zero/zero conditions.

There seems good prospect of obtaining a solution to the problem of regular operation in conditions of low visibility, provided that the final landing manœuvre can be made visually. There remains the problem of maintaining regularity when visibility deteriorates below this standard. A number of solutions have been suggested, some of them used during the war (see Fig. 9), but nothing fully satisfactory has emerged yet. I suggest that the objective of *research and experiment*

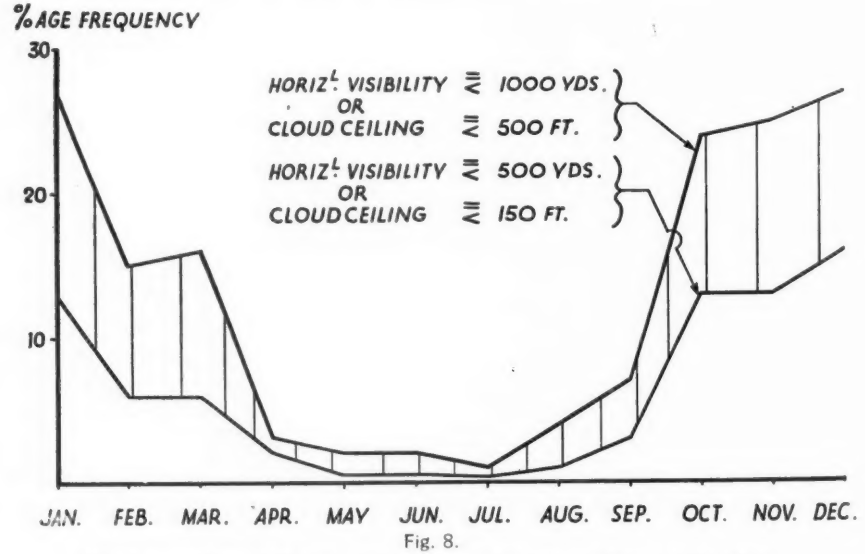

Fig. 8.

Weather minima—Influence on regularity. Average conditions at Northolt.

	Aid	Action of Aid	State of Development and Use	Cost
1.	F.I.D.O.	Clears fog from runway by thermal means	Successfully used during war at emergency landing fields. Now being rehabilitated at Manston and Blackbush	Very costly in installation and use
2.	G.C.A.	Gives to controllers precise information of plan and elevation of aircraft in relation to runway	Successfully used by Services in U.S.A. Now installed at London Airport and successfully used there	Requires a number of special staff to operate
3.	High intensity lighting	Defines runway in low visibility conditions	Experiments in progress in U.S.A. and Great Britain	Moderate
4.	Automatic blind landing	Ground beam controls flight path and landing manœuvre via aircraft automatic controls	Experimental	Small—additional use of existing equipment
5.	Long travel undercarriage	Reduces landing shock when aircraft is flown into runway direct from approach path. Could be used in combination with 4	Experimental. One aircraft equipped by A.W.	

Fig. 9.
ZERO-ZERO AIDS.

should be to modify the conditions by artificial aids, to make possible a *visual landing*. FIDO will do this in fog; but FIDO is very expensive, at present, in installation and in use, and there seems little prospect of developing it into an aid for use at all airports.

Experiments are being made with high intensity lighting in this country and in the U.S.A., with some measure of success; there is a reasonable prospect that the system of high intensity approach and runway lighting being developed at the Royal Aircraft Establishment may provide the answer in all but the thickest fogs. In zero/zero conditions, there remains the difficulty of marshalling aircraft on the airfield; this, of course, is a problem of safety *in all weathers* and radar devices will, in due course, be used by Airport Control to marshall aircraft in clear weather. A combination of this with high intensity lighting on taxi tracks might offer a reasonable solution, in the same way as G.C.A. might be used to monitor a landing using high intensity lighting. In the writer's opinion dense fog will always slow up operations so that reliability will be lost, although devices may be developed in the course of a few years which will obviate cancellations. Air will then be in much the same case as shipping, trains and other forms of surface transport.

4.6. REGULARITY AND AIRCRAFT DESIGN.

4.6.1. *Maintenance.*

Brief comment is needed on the roles allotted to designer and operator in Fig. 6—the headings are not comprehensive, but cover the important matters. Maintenance is perhaps the most relevant operational division in its possible effect on reliability. But the need to ensure first-class maintenance on the score of safety and economy is so overwhelming that it is unlikely to be a factor in reliability, so far as the situation is within the control of the operator. Lack of spares, for instance, in this world of controls and bottlenecks may easily lead to widespread unserviceability, unreliability and irregularity despite the best of planning. But this, we hope, is ephemeral.

4.6.2. *Flying qualities.*

Major airports must have the highest possible utilisation, *i.e.* the scheduled movements under conditions of low visibility will tax to the limit, consistent with safety, the controllers and equipment. Such a scheme cannot allow for missed landings or aircraft arriving out of schedule; when these occur the aircraft will perforce join a queue and may have to wait a long time. The flying qualities of the aircraft, its performance and the standard of navigation all enter into this. Factors for the designer to consider are:—

(a) stability and control, particularly at approach and low cruising speeds, in manual or automatic control; good landing qualities.

(b) behaviour in rough air.

(c) flexibility in performance, with economy.

The conditions are onerous for the pilot; he has little time to make corrections prior to landing after emerging from cloud under low ceiling conditions. Hence the need for really good handling qualities in the approach and landing manœuvres and I suggest research is still needed on this problem. The crew may have become fatigued during the flight because of unsatisfactory stability or control qualities in cruising conditions in rough air. Such characteristics are probably more fruitful of pilot fatigue than any other single cause.

If the pilot is to make the best use of the aids provided he must not be in a tired state when he comes to the crucial let-down at the termination of his journey. Good flying qualities and the best possible layout of his controls will minimise his fatigue, and hence be a very real contribution to the solution of the problem of reliability. Research is needed into the problem of cockpit layout and indeed, of the best arrangements for the pilot for blind flying.

5. PROBLEM 2—SAFETY (WITH ECONOMY).

Lord Nathan, in one of his early speeches as Minister of Civil Aviation, called far safety first, safety second and safety third in civil air transport. No one denies that safety is essential, but it must be remembered that safety is not absolute in an engineering sense. The problem is to ensure the highest standards of safety as economically as possible; this need has wide repercussions, as I shall attempt to show. In Fig. 10 are shown the main agents and activities contributing to safe airline operation, *i.e.* an operation in which all reasonable steps are taken to ensure safe transit of passengers and goods. Division of responsibility, operator or other authority, is clear in many cases, as indicated in the figure; in the remainder, the operator plays a part to a varying degree. For example, in design the major responsibility rests with the designer, but he must look to the operator for definition of his requirements. These may be quite fundamental as, for example, in definition of standards which will result in simplified pilot and crew training.

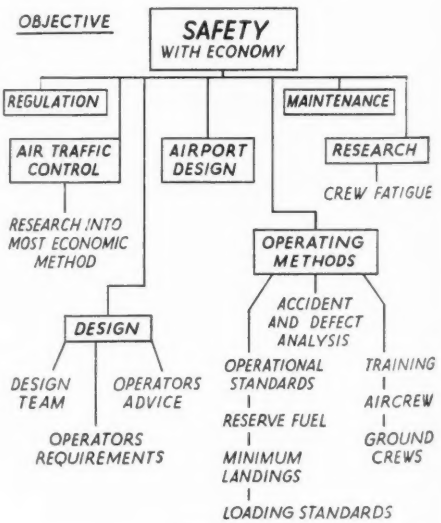

Fig. 10.

5.1. AIR TRAFFIC CONTROL.

The primary objective of air traffic control is safety, but its potential influence on overall operating economy is great and in this sense it is a first-class example of the type of problem I have in mind under the generic term of "Safety with economy." In fact, it is only by considering it in this way that it can be seen in correct perspective as an integrated whole and not simply as a means to safety in any one area, or at any one airport.

I submit that within the primary objective of safety, the system of air traffic control must be so developed as to achieve the following objectives:—

(i) Maximum utilisation of airports (implies assessment of alternative methods of control including varying complexity and weight of equipment on aircraft);

(ii) Maximum economy of aircraft (minimum interference with ideal traffic in terms of its best "trajectory" and "uncontrolled" time);

(iii) Best economic balance between weight, complexity and cost of equipment to be employed in the aircraft and on the ground, taking account of training and maintenance, related to airborne and ground equipment.

The overall assessment of relative methods and costs must take account of the factor of regularity in stimulating air traffic.

In this matter I think there is a danger of accepting as inevitable, a form of control which is rigid within an extended zone around busy airports. Such forms of control were developed under military conditions in this country and, as a result of a particular method of airline flying in the U.S., *i.e.* the combination of the airway or radio range and the scheduling on the basis of C.F.R. conditions, which entailed congestion and "stacking" in I.F.R. conditions. Such rigidity may ensure safety, but there may be other ways of obtaining an equal, or even higher, standard with much less difference in timing of movements between C.F.R. and I.F.R. than those we saw earlier. For example, one can imagine aircraft having such means of navigation for all stages of a flight and such performance as to be capable of maintaining a pre-planned schedule in time and space at all stages of the journey from take-off to landing. The type of air traffic control needed to handle fleets of aircraft so equipped operating on schedules planned for I.F.R. conditions, might be quite different from the kind of control we have now.

We are never likely to have an ideal world, but unless the problem of air traffic control is correctly formulated and tackled then we shall be groping without a clear objective. The problem is highly complex and its solution will involve much research work, in particular the study of various methods of control, taking account of the practical developments to be expected from aids to long and short range navigation approach, landing, taxying and take-off; the probable development of aircraft, especially turbine-engined aircraft; flying and landing under automatic control; costs of new airports; the development of new and improved equipment and especially, the practicability of getting such equipment fitted and into use on a world-wide basis.

As an example of the conflict of interests, I can quote the effect on aircraft economy of the present system applied to a turbine-propelled and turbine jet type. In the first case, taking a medium size aircraft suitable for short/medium stages, there is a loss of operating economy of about 5 per cent. at a representative stage distance. For a long-range jet-propelled aircraft the effect on economy varies with range. It is most simply expressed as a reduction of over 8 per cent. of maximum payload. These estimates are based on flying at 5,000 ft. in the control zone of 30 miles radius.

But it is abundantly clear that we cannot tolerate a stacking system of control with jet propulsion. In the case of the same jet-propelled aircraft, the cost in fuel of 15 minutes orbiting at 3,000 ft. is equivalent to about 100 nautical miles in normal cruising flight at the cruising height of 35,000 ft. Thus, to avoid being forced to modify our scheme of control when such aircraft come into use, we must take time by the forelock and introduce by stages what will become our final method.

5.2. SAFETY WITH ECONOMY—OPERATORS' PART.

The operator is naturally vitally concerned in this problem. His operation must be safe and he cannot compromise; but it must also be economic. His problem, then, resolves itself into developing methods of operation and training while using his existing equipment and ensuring, so far as he can, by speci-

fication and guidance, that his replacement types shall have the most economic qualities in this context. Let me carry the argument a little farther so that you may see clearly what I have in mind.

The elements of our problem are the aircraft, the crew, the ground organisations, in use under all conditions, including those of emergency. Each element separately is made a safe link for the operation; it is in the interlinking that the opportunities arise for making economies. For example, an aircraft which is simple, easy to fly, having in addition no vicious or difficult characteristics under emergency conditions such as an engine cutting in flight or at take-off, will facilitate training, make it easier and hence, cheaper. This is an important means of economy since all captains of aircraft must, as a safety precaution, be checked for proficiency at six monthly intervals in the critical phases of airline flying, such as flying and letting down under "blind" conditions, engine cutting in various stages of flight, and so on. This involves a double expense in the use of aircraft and in the use of pilots for other than revenue-earning flying, so that it is important to reduce so far as possible, the time necessarily spent on it. Good flying qualities allow this to be done and hence, promote economy while in no way derogating from safety standards.

Another example of a different kind, complementary to the problem of air traffic control, is the use of such navigational and ground aids as will enable a safe operation to be run under all conditions of weather, thus ensuring reliable, regular service with the overall economy which goes with it and a direct economy by reduction of fuel reserves.

5.2.1. *Discussion of relevant aspects of future requirements.*

It is in the appreciation of the nature of his problems and hence the specification of his requirements for future types, that the operator can contribute most. It is true that the onus of responsibility is then placed on designers of aircraft, engines and equipment, on those responsible for development of ground aids for navigation, approach and landing and so on, but the essential first step must always be the formulation of the problem. Some of the problems which may appear in this context are:—

(a) The desire to reduce the danger from the engine cut emergency may lead to the demand for three- or four-engined types where a twin might be suitable on other grounds. A major incidental economy may be the use of smaller airfields.
(b) The demand for flying qualities in cruising flight to minimise crew fatigue, especially in blind conditions.
(c) Flying qualities to make blind approach and landing simple.
(d) Equipment, lighting installations, cockpit layout, and so on, to reduce crew fatigue.
(e) Low noise and vibration to reduce crew fatigue.
(f) Use of safety fuel to minimise weight spent in fire precautions.
(g) Devices such as the long travel undercarriage to facilitate blind landings, hence regularity and economy.

I place very high on the list the design of flying qualities which will make the critical manœuvres of approach, landing and take-off simple and straightforward. As cruising speeds and hence frequencies of operation increase, these manœuvres will be of more frequent occurrence in a given total flying time. The effect of such flying qualities will be to make operations safer, to reduce the time spent on training and refresher courses, and to improve regularity and hence, overall economy. Airport utilisation is also likely to be improved, an extremely important consideration for the future.

Equally important is the reduction of crew fatigue; many factors enter into this, a major one being good qualities of stability and control in cruising flight, especially in the fore and aft plane. There is no need to stress the importance of crew fatigue in relation to safety. There is, however, the aspect pointed out by Sir Ralph Cochrane in his lecture to the Society in January 1947, namely that many accidents attributed to pilot error should rightly be ascribed to other factors, *e.g.* instrument layout, noise and vibration, handling and flying qualities, indifferent navigational aids and so on, which, by causing pilot fatigue, have been the basic cause of the error of judgment. It is the design of the aircraft which requires improvement rather than the standard of piloting. *I am sure there is urgent need for research to assess the conditions of crew fatigue peculiar to civil airline operation, having in mind the onerous conditions of operation to schedule in all weathers with extra responsibilities for passenger safety and comfort.*

5.2.2. *Accidents in relation to future requirements.*

A broad analysis of the accidents in the U.S. and in this country in 1945 and 1946 shows the preponderance of accidents during the take-off and landing manœuvres—or, even more pronounced, the number caused by impact with the ground. For comparison, similar information for 1925-1930 shows the high proportion of accidents in flight. The conclusion seems inevitable that for a given amount of traffic in a route system, aircraft types should be so chosen that landings and take-offs are reduced to a minimum. In this case, we see clearly how the requirements for new types of aircraft may be affected by this idea of safety with economy. Of course, as we push farther into comparatively unknown country in terms of increased speeds and height of operation, there may be again a higher proportion of accidents in flight, but I think the natural hazards of take-off and landing will always remain and we should avoid them as much as we can.

6. ECONOMY.

6.1. AIRCRAFT AS BASIC FACTOR.

Economic operation must always be the final touchstone of any fully established airline. It reflects the overall efficiency of the organisation. But it is not enough to be economic; we must make air travel cheap so that it may be used increasingly by the mass of the people and for the transport of merchandise. The fundamental factor is the aircraft. This is the revenue earner and if, because of its inherent qualities, such as low relative payload, high unserviceability because of poor maintenance features, low performance, and so on, its direct cost of operation is high, then no amount of administrative excellence in reducing overheads will make the operations economic.

A good example of what I mean is the D.H.89, an aircraft built first in 1934 to carry 6 to 8 passengers at a cruising speed of 125 to 130 m.p.h. which gave excellent service on the routes for which it was intended but which now, under current conditions in B.E.A. earns less per hour than the direct costs of operation. The reason for this is mainly because of present-day costs such as high landing fees; in fact, as you saw in the Press not long ago, the cost of the landing fees on the Cardiff-Weston-super-Mare shuttle service on which this aircraft was used, was 85 per cent. of the revenue.

6.2. THE DAY-TO-DAY PROBLEM.

The margin between revenue earning potential and direct operating cost is obviously the measure of the problem of making operations economic with a given type of aircraft. This is the day-to-day problem. Equally important is the problem of replacement aircraft and new types, since these give us the opportunity to provide the cheap transport referred to earlier.

Taking to-day's problem first, what factors in the operation can be used to improve economy? This is a matter of making the best use of existing equipment.

6.2.1. *Direct operating costs — maintenance and economy.*

The unit of production of air transport is the product of the unit payload and the unit distance moved, *i.e.* the passenger-mile, ton-mile, tonne-kilometre. The direct cost of producing this unit is the measure of the basic economy of a given aircraft type. It depends primarily on the cruising speed and relative payload, provided that the utilisation, *i.e.* the total hours of revenue-earning use of the aircraft per year or during its life is reasonably high.

The simplest way of showing the relation is by the expresion: —

$$C = \frac{1}{fW_pV_b}(C_s + C_f) \quad \text{(Fig. 11)}$$

where C = unit direct operating cost { pence/tonne-kilo; pence/ton-mile; pence/passenger-mile }

f = load factor = Payload carried / Payload capacity for the stage

W_p = payload capacity for the stage

V_b = block speed = Stage distance (D) / Total time of journey, start to stop

C_s = fixed charges plus operating costs per unit time

C_f = fuel cost per hour. (Sensibly independent of stage distance.)

In considering this expression for a given aircraft type, it is clear that the only factor susceptible of variation is C_s, which depends on rate of use, *i.e.* operational hours per year and maintenance charges. These are intimately inter-connected since, as is well known, if maintenance time is excessive, utilisation cannot be high. As compared with other forms of transport, maintenance has a much greater effect on operational time

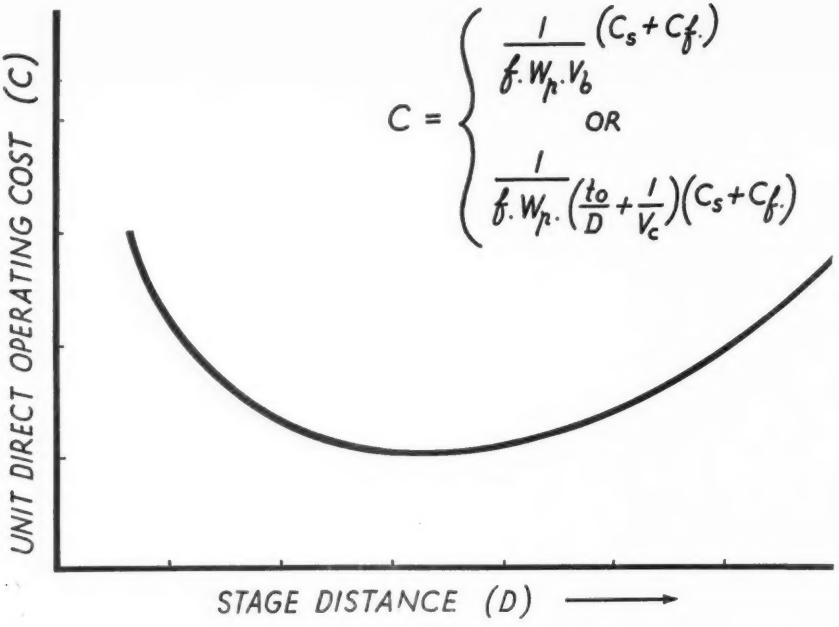
$C = \begin{cases} \frac{1}{f.W_p.V_b}(C_s + C_f.) \\ \text{OR} \\ \frac{1}{f.W_p.}\left(\frac{t_o}{D} + \frac{1}{V_c}\right)(C_s + C_f.) \end{cases}$
UNIT DIRECT OPERATING COST (C)
STAGE DISTANCE (D)

Fig. 11.
Diagram of direct operating costs.

f = load factor
W_p = payload available for stage
V_b = block speed
V_c = cruising speed
t_o = time for (taxi + take-off + landing + excess in climb and glide)
C_s = fixed charges + operating costs per unit time
C_f = fuel cost per unit time

because of the frequency of inspections and the time taken to complete them, done at 25, 50, 200, 400-hour periods, in addition to a daily inspection of fitness for flight. This high degree of inspection is a reflection of the complex nature of the vehicle we are dealing with in air transport, and the necessity for safety. Reduced maintenance may have a double effect on cost, first by increasing the time available for operation and second, by reducing the cost of the work.

These effects are illustrated diagrammatically in Fig. 12, the dotted lines showing the changed conditions. The dotted horizontal line represents the unit fare and the improvement in the margin between unit revenue and unit cost is clear. Total *revenue*, of course, is further increased in the ratio of utilisations U_2/U_1, *provided* that the increase in traffic capacity made available can be effectively used. In a given route system, the increase in utilisation implies an increase in frequency of operation on the routes which may be reflected in a reduction of load factor. Expressed in another way, the effect of maintenance in improving utilisation is to allow the same traffic to be moved with a smaller operating fleet.

The importance of maintenance in economic operation cannot be over-emphasised. With a given type in which the design cannot be substantially altered, maintenance time can be reduced only by improved facilities and organisation of the work. A remarkable improvement in maintenance in B.E.A. is being achieved now by application of these principles. For future types, the matter is in the hands of the designers, advised by operators.

6.2.2. *Economy and utilisation.*

The economic benefit of increasing utilisation can be seen from the diagram. It is not confined only to the aircraft, but includes the staff, buildings, and facilities of all kinds, as is clear from the curve of overhead costs,

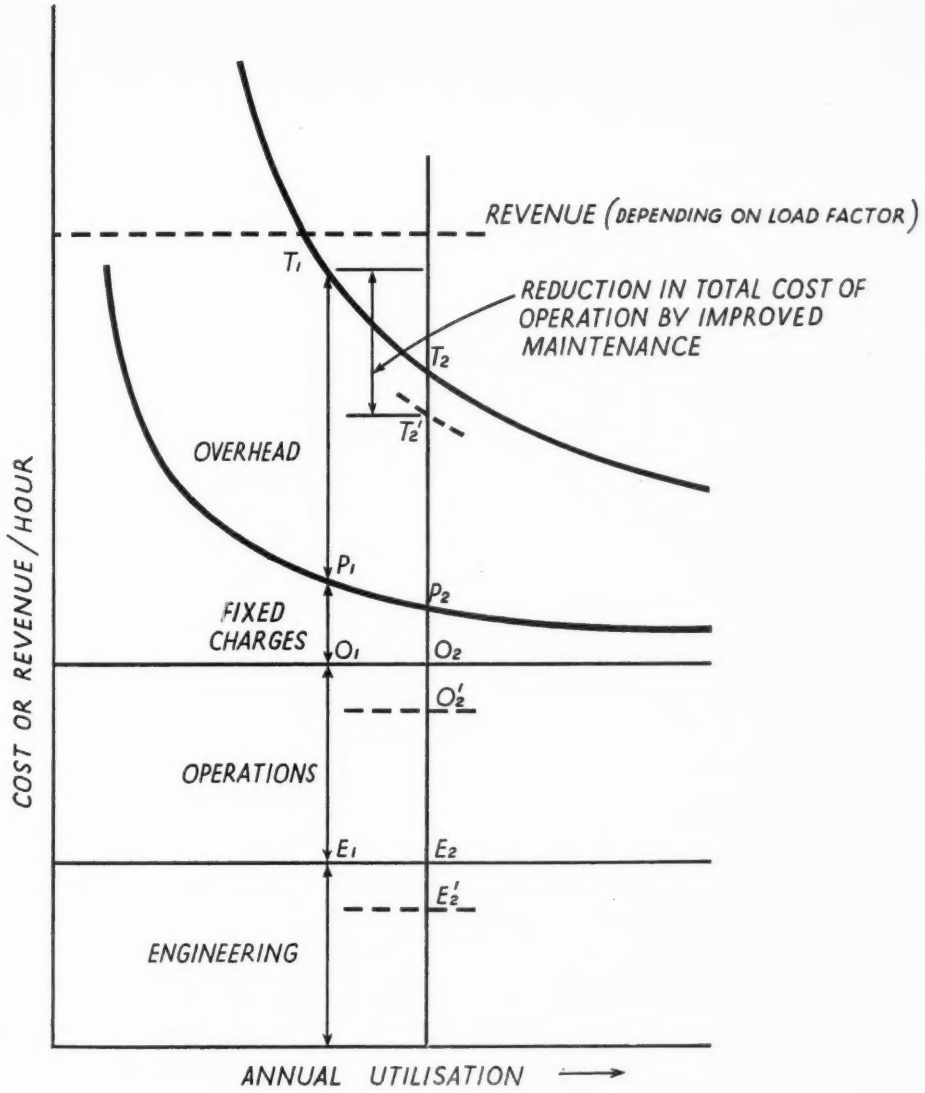

Fig. 12.
Diagram of utilisation and cost.

which is drawn on the assumption that the overhead is designed for a fairly high utilisation. These conclusions are, of course, only valid provided that traffic can be built up at the increased frequency implied by the higher utilisation, so that the load factor remains sensibly constant.

6.3. NEW TYPES—INFLUENCE OF SPEED ON ECONOMY.

From the above it is clear that the means of obtaining improved economy with existing types of aircraft are strictly limited. The solution to the problem of *cheap* air travel must be found in the new types of aircraft yet

to be built; *the main responsibility then rests with the operator in specifying his requirements,* and with the designers in meeting them in collaboration with the operator. Here the operator has a peculiarly onerous responsibility, since he must not only formulate his problems correctly, but he has to look eight to twelve years ahead, since it takes six to seven years to get a new type into operation from the time requirements are first thought of and it must give good competitive service for upwards of ten years. He must, therefore, look for sober, reliable, estimates from designers—airframe, engine and equipment—of what is likely to emerge in practical form in this long-term view. If too much is attempted, there is the risk of protracted development, the aircraft finally arriving out of due time; on the other hand, lack of enterprise in design may result in a non-competitive aircraft. The problems arising are discussed below, including that of the development of new types so that they are in a state fit to give efficient service when they reach the operator.

6.3.1. *New types—major factors in direct cost.*

As a first step, we may give a little more consideration to the expression for direct operating cost. It may be re-written:—

$$C=(1/f\,.\,W_p)\{(t_o/D)+(1/V_c)\}(C_s+C_f)$$

where V_c = steady cruising speed at best height

t_o = time for (taxy + take-off + landing + excess time in climb and glide).

To a first approximation, we can say that C_s and C_f vary as total weight W. Then for a given utilisation and stage distance we see that direct operating costs vary inversely as the ratio of payload to maximum take-off weight. In other words, weight per passenger is the most significant single parameter in considering direct costs for a given stage distance. Cheap air transport can only be obtained by a marked reduction in all-up weight of aircraft per passenger. This is a much more direct and simple method than, for example, increasing speed to improve economy, since it may not be possible to use the speed to the best advantage. The most effective factor in design to this end is the reduction in structure weight and, of course, in the weight of equipment and amenities which are specified by the operator as essential for safety and comfort. Taking t_o as one-third hour, a reasonable value, it is clear that V_c becomes a dominant factor at distances beyond about 1,000 nautical miles, but only if the other variables can be held reasonably constant. This implies at increasing values of V_c not only lower aircraft drag for a given power plant (*i.e.* keeping C_f constant), but also avoiding any substantial increases in manufacturing and maintenance costs and maintenance time due to increase of cruising speed. At shorter stages cruising speed has decreasing importance as a major parameter, *e.g.* at 200 nautical miles stage distance the effect on direct cost of varying V_c alone is as follows:—

V_c (knots)	200	350	400
Index of speed	1	1.5	2.0
Index of direct cost	1	0.75	0.625

i.e. doubling cruising speed saves only 37½ per cent. direct cost.

6.3.2. *Economic use of speed.*

It is clearly of fundamental importance that the speed shall be usable, *i.e.* that the increased frequencies, implicit in the use of higher operating speeds in a given route system and at an economic utilisation, can be generated without any pronounced decrease in load factor. For this reason, high speeds become increasingly difficult to use as stage distance decreases. This is illustrated by Fig. 13, which shows how frequency, speed and stage distance are related for a daily utilisation of eight hours, which is convenient for maintenance periods and would result in a satisfactory annual utilisation. Bearing in mind commercial timings (in general concentrated in the morning and evening on the shorter stages), it can be seen that the high speeds may lead to unsuitable frequencies and timings at stage distances less than 500 nautical miles. Obviously much depends on distribution of population and conclusions reached in regard to, say, the Eastern area of the U.S.A., would be quite invalid when applied to Europe.

6.4. FORECASTING TRAFFIC.

The above illustrates in simple terms some of the many problems to be solved in obtaining the cheap air transport which is our objective. Everything rests on obtaining the right aircraft for the work to be done, *i.e.* to fit the route system. The first thing, then, is to define the task. Here a peculiar difficulty arises. Peculiar, that is, to the field of air transport. It arises from the protracted time taken to bring a new type into operational

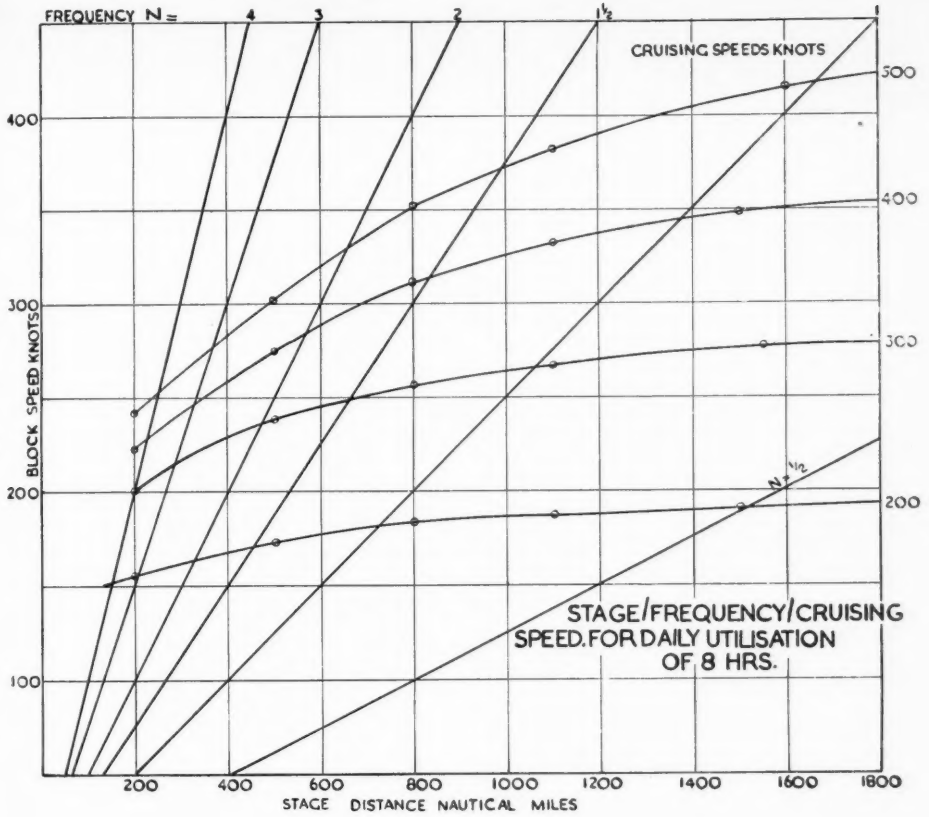

Fig. 13.

use after initial specification of requirements. Depending on the size and complexity of the type, this may be a period of four to eight years, and it becomes necessary to forecast not only traffic in the area as a whole, but over specific routes in regard to volume and frequency. This is a major problem. It was touched on by Edward Warner in his Wilbur Wright lecture in 1943, when he suggested that traffic between two towns varies directly as the product of the populations and inversely as the distance. It has also been studied by Platt, who concluded that the law is best represented by the square root of the product of the populations and inversely as the distance. Presumably both refer to maximum demand after the traffic has been steadily developed for some time. Hence there are two aspects of the problem:—

(a) the development of traffic;

(b) catering for the full potential traffic;

and these must affect the choice of aircraft in an operating fleet since both phases must be handled economically, if possible.

6.5. Development of new types of aircraft.

The development of new types of aircraft to the state when they are fit for civil operation is a new problem of administration and finance arising out of three main factors:

(i) the increase in size and speed of the types needed;
(ii) the increase in complexity and quality to meet requirements;
(iii) the rising costs of research, design, labour and materials.

This problem must be solved if we are to have for future operations a steady succession

of replacement aircraft, as we have had in the past. The problem has two main parts; first, the design and construction of a prototype and, second, the flight development over the routes to find out and correct those faults which, if allowed to remain, would cause protracted unreliability and uneconomic running in operation. The operator is vitally concerned in both parts; he alone can give to the designer the interpretation in detail of his main requirements as affected by his standards, methods and experience in all phases of operation—piloting, navigation, training, crew fatigue, passenger comfort and especially, maintenance. In fact, he must be brought in as an essential member of the design team. But the operator cannot develop aircraft and operate them at the same time; it is too expensive. He is, however, an essential partner in the process, which may be best done by operator and constructor conjointly, although each may look for financial support from national resources. I think our American friends are moving towards this idea of financial support from the national purse for the development of new types.

The period of development may be a contentious subject, but in my view it should at least cover a full year of flying and two major overhauls of airframes and engines, *i.e.* upwards of 1,000 hours. This process will undoubtedly be expensive; but by forestalling operating and engineering troubles in service it will prove an overall economy. It will also give opportunity to work out economic maintenance processes and hence promote good utilisation from the outset. It is worthy of note that the Constellation had about five years of development prior to use by civil operators.

6.6. Minimum number of types.

A further problem influencing economy for the future is that of the number of separate types of aircraft needed to provide adequate air transport throughout an area of operations. The nature of the problem depends on the varying character of the traffic, the degree of separation of zones of dense population and the need to serve isolated areas of scattered communities and sparse populations, but it is quite clear that the number of types should be reduced to the minimum consistent with service to the community as a whole. The U.S.A. has shown the most economical form of operation when at one stage practically all the traffic was moved in the ubiquitous DC-3. Scheduled airline operation was reduced to its simplest form; perhaps the apparent simplicity misled both the Americans and ourselves as to the real difficulties and problems involved in air transport and its growing development. The B.E.A. route system exhibits in a peculiar degree the characteristics demanding ideally a large number of types and hence setting a problem in service and economy, in the compromise to be made in reducing the numbers of types. This basic difficulty is intensified by the high variation in seasonal traffic and the high proportion of pleasure and tourist traffic under normal conditions.

The principle of minimum number of types has wide implications, leading to as high a degree of standardisation as possible throughout a fleet, *e.g.* common basic design for passenger and cargo carrying; common navigational aids; use of same power plant in different types and so on. Here I suggest we see a problem of international standardisation, especially in those elements of design or use which have a bearing on safety. Perhaps the I.C.A.O. organisation intends to handle this, but it will clearly need the most careful treatment to avoid handicapping new ideas or stultifying invention.

6.7. Economy and international organisations.

The whole problem of economical operation is now inseparably linked with the decisions of the international organisations, I.C.A.O. and I.A.T.A. It is essential that operators should have the quality and number of staff effectively to present and argue their case at national and international conferences. Many of the questions raised are of wide national significance, and it would be a just recognition of responsibility to make a grant specifically for this service out of national funds.

7. SUMMARY.

To summarise, in my view the main problems facing airline operations are:—

(i) the provision of reliable and regular service in all reasonable conditions of weather and climate involving the solution of navigational and traffic control problems in low visibility; the provision of first-class flying qualities of aircraft, especially in the approach and landing conditions; the develop-

ment of aids to visual landing in low visibility conditions; the solution of present problems of pilot fatigue, and so on.

(ii) the *economical* achievement of the highest standards of safety, *i.e.* safety with economy, involving a correct appreciation of responsibilities as between operators and regulatory authorities; the best use of air traffic control in relation to overall economy; full development by operators of standards and methods of operation and training schemes to this end; and full appreciation of the problem in formulating new requirements.

(iii) to reduce the cost of air transport, mainly affected by the provision of the aircraft best suited to defined tasks—hence the problems of defining the tasks, of employing the minimum numbers of types of aircraft to discharge a wide variety of duties and the best use of those aircraft.

DISCUSSION

Sir Conrad Collier, K.C.B., C.B., C.B.E. (*Fellow*): It was impressive how every aspect of the problem and every agency interested in it were so closely linked together, so that every development in any part of the organisation would inevitably affect the whole problem. That seemed to show the need for the closest collaboration between all in the Industry—those concerned with safety regulations, those responsible for negotiating international standards and regulations, the operators, the Air Registration Board, the Ministry of Supply—and unless there were the closest team work by all concerned, there seemed to be many chances of misunderstanding and of failure to achieve the end.

It was of immense importance to everyone interested in civil aviation that the operators and all others concerned should watch I.C.A.O., because anything that was decided after discussion by that body and was put into international regulations might affect, to a very large extent, the economy of operations and other aspects of civil aviation.

One of the most direct means of effecting greater safety and improving economics was to cut down fuel consumption; Mr. Rowe had shown plainly that that aspect was not only essential to control, but to economics, because it reduced the weight of the aircraft.

It was generally agreed that the air traffic control problem needed research and development and they were likely to need some place where they could practice new techniques in the air. He would like Mr. Rowe's views on that; the difficulty in civil, as opposed to military aviation was in practising new ideas; when the scientists and the operators were brought together and produced the new ideas, they would need to try them out experimentally before introducing them at and around international airports.

Professor A. A. Hall (*Fellow*): Mr. Rowe had based some of his points on "actual" meteorological data, rather than on "forecast" data. But the operation of aircraft over stage distances which were other than small would, he imagined, be conditioned by the forecast, rather than the actual weather. How was the comparison between cancellations or delays and weather influenced by using "forecast" weather rather than "actual" weather?

The traffic control problem was rightly stressed as an outstanding difficulty facing civil aviation. Simple statistics showed some interesting points concerning it. There were two "extremes" in the type of arrival pattern; at one end, the entirely random arrival, and at the other the completely ordered arrival, quite accurately to schedule. If aircraft arrived absolutely on time, and if the schedule were suitably arranged, the rate of arrival could equal the maximum landing rate of which the airport and its facilities were capable. If the arrivals were completely random, the allowable average rate of arrival must be around one half the airport's possible landing rate, for, if arrivals were random the chance that in some period the rate of arrival would be twice the average was substantial. From this viewpoint, one object of the control system was to convert what would otherwise be random arrivals into as ordered a pattern as possible, so increasing the permissible safe utilisation of the airport. Two systems (GEE and omni-directional range) were quoted in the paper. Was it known what were the capabilities of these systems from this point of view? He would be surprised if they could be regarded as producing a fully ordered arrival pattern; what was the ratio of "maximum permissible average arrival rate" to "airport maximum

landing rate" when they were used? If the figures were not known, it should be possible to get them by suitable research at the airport, and such operational research was deserving of encouragement.

Mr. Rowe had hardly mentioned the word "passenger," but there were problems in which the passenger played a part. The improvement in economy with increase of speed depended on passengers using the faster service to such an extent that higher frequencies could be maintained at high load factor. There were questions of comfort; the fast service would have to be comfortable, and trouble from bumpy weather might be more frequent in faster services. What were the criteria for passenger comfort?

The passenger was concerned with total elapsed time, including time taken up by the Customs and Immigration Officers. An aircraft which flew a little slower than another, but which could carry the officials, and allow clearance of formalities in flight, might be the more attractive of the two to the passenger, by showing a smaller total elapsed time.

He asked for good booking arrangements, in order that planning an air journey might be as painless as possible. The basis of ultimate economy was more and more passengers; one would not get them by making booking a major undertaking, as it often turned out to be at present.

B. Kaiser, M.B.E., A.M.I.Mech.E. (*Assoc. Fellow*): The improvement of mechanical reliability was intimately associated with maintenance, and mechanical unreliability was the maintenance engineer's headache. The inability to rely on the various mechanisms in an aircraft performing to a specified number of hours resulted in uncertainty of the volume of work, and the general principle of "reject on condition," *i.e.*, the decision as to whether a component or accessory needed removing, depended on the individual examination of every part; in other words, there were as many standards as there were Inspectors. That, in turn, resulted in maintenance being the familiar pattern they all knew, namely, a series of emergencies.

That inability to forecast and plan the arisings of work resulted in: —

(a) Unbalanced flow of work in hangars and workshops.

(b) Inability to forecast spares requirements. Usually, to cover that, spares were ordered to arbitrary standards far in excess in respect to some items, others being missed completely.

(c) The whole maintenance programme was thrown out of gear and the staff, from the chargehand to the chief engineer, were largely occupied in chasing the bits and pieces, all urgent.

True, some attempt had been made to establish the failure rate, maybe on the number of defects per 1,000 hours. Imagine what that meant! To establish the life of a component they had to wait until a defect appeared, conscientiously plot it, hoping that the defect was not sufficiently serious to cause disaster.

Several airlines, particularly in America, had laid down their own standards of life for components and those standards varied from company to company.

One of the greatest problems facing British civil aviation was the maintenance problem and he thought it had not received the detailed scientific study and analysis comparable, say, to that devoted to the design of aircraft. He suggested that first, they should study depreciation of the aircraft structure and components as a research programme and try to establish, through quality control methods at the manufacturers' and maintenance bases, factors showing the rates of depreciation of the various items leading to guaranteed life hours for those components, *i.e.* a time-life on which the maintenance engineer might plan his workshop.

Dealing next with ground facilities, and particularly the design of hangars, he gave as an example an airline having a fleet of 30 aircraft and, say, three or four hangars, each capable of housing six or seven aircraft. Some 60 per cent. of the fleet might be serviceable each day, arriving at the maintenance base in the evening for all-night maintenance. To put that number of aircraft through the hangars in the limited time available, at the same time keeping the hangars sufficiently heated to permit comfortable working conditions, was a major problem in industrial efficiency, particularly if the hangars were of the usual pattern, *ie.* rectangular, with doors at the end.

It was probably not generally realised that the shape of the hangars predetermined the pattern of the maintenance methods. For instance, a long, narrow hangar with doors at each end meant that the maintenance engineer must adopt line flow maintenance, *i.e.* aircraft must move through the hangar in

sequence. The inability to forecast the work accurately resulted in bottle-necks and intermittent flow, with consequent effect on the punctuality of services.

On the other hand, a hangar with doors down one side made the dock system of maintenance advisable. He, personally, was inclined to the view that hangars should be designed on a unit system, each unit being capable of housing one aircraft dock, the units being increased to suit the various sizes of fleet used by the operators. In any case there was room for a research programme into the problem of hangar design.

It was pleasing to note that the R.A.F. were fully alive to the problems of maintenance, and their "planned inspection" methods represented a scientific approach to the economics of maintenance. They probably led civil aviation in this respect.

He had grave doubts that, whatever the reduction of costs obtained by increased maintenance and operating efficiency, the present administrative structure of British civil airlines would impose a burden of overhead charges on the revenue-earning departments which would be like the old man of the sea clinging to Sinbad the Sailor's shoulders. It appeared to him that there was an optimum size of any organisation which was capable of being run efficiently, and that size was determined by the methods of organisation which were introduced to retain day-to-day control of the functionary departments. It was also necessary to reconcile the conflict between the two types of authority which appeared in large organisations, *i.e.* the specialist or functional authority and the co-ordinative authority, if they were to be efficient, and above all to avoid the "Headquarters mentality."

G. R. Edwards (Vickers-Armstrongs, *Fellow*): His main impression was that the aircraft designer looked like getting the customary chastening, although perhaps not so forcibly as on the occasion of Mr. Bain's recent Empire Lecture—and he felt uneasy when considering Mr. Rowe's only-too-true picture of the irregularities and delays occasioned by factors which were outside the aircraft designer's control. There was uneasiness because they knew from long and bitter experience that what might be other people's shortcomings were more than likely to descend upon the aircraft designer; that, as an example, the apparent inability to reach a consistent standard of navigational aid would mean that a large part of an aircraft was cluttered up with every combination of aids, including radar and radio, which the area over which the aircraft had to operate was likely to demand. Further, now that concrete was so difficult to obtain, the one-time popular practice of making runways longer and longer was perhaps on the wane. Thus they knew that the things they would like to do to the aeroplane would be limited considerably by the size of the aerodrome on which it had to be accommodated. Also, it was fairly clear that this generation of bright new aircraft, to which they had been encouraged to contribute, had a very fair chance of its brightness being dimmed by the absence of the ground facilities which were so important to its successful and economic operation.

In short, the crystal into which they had gazed three or four years ago had a little distortion in it. To quote only one aspect as it then appeared: the apparent facility with which turbine-engined aircraft would be able to hurl themselves from one place to another, straight off one piece of ground and straight down on to another, without any question of waiting fifteen minutes or two or three hours, meanwhile consuming vast quantities of fuel —a problem which had given them tremendous worry for the past two or three years—did not now appear so good; the picture they had seen in the crystal a few years ago had not come out quite to the shape they had thought it would. That might be a painful realisation, and he felt they should echo Mr. Rowe's remark that the operators, in advising the designer of the type of aircraft he had to produce, had a very heavy responsibility. Possibly, he might be speaking for some of his brethren if he stated that he really did agree about that! The operators had a considerable responsibility in deciding on the sort of aeroplane that was going to be used in the far-off days, when the designer's somewhat unfortunate efforts had been hammered and pushed, flown and mangled and taken to pieces and put together again, and then found to be a thoroughly unsatisfactory article, or so completely out of date that nobody wanted it, or so advanced that the aerodromes into which it should operate did not appear to be able to receive it!

He agreed that one of the prime factors before an aircraft designer was to ensure that his aeroplane was maintainable. A most highly efficient structure was not a great

success if they could not get anything out without the aid of a tin-opener or some sort of explosive! But it was not all on the designer's side. When they had to deal with a variety of operators all over the world, the varying standards of maintenance which existed from one to the other were impressive. He was interested to read that some of the American airlines, whose maintenance had always been held up as a wonderful example for all and sundry, had seriously considered and were, in fact, applying, a system of sub-contracting of the major maintenance. Organisations specially set up for the purpose, in some cases offshoots of the firm which had built the aircraft, were doing some of the major maintenance; and to their astonishment the operators had found that they were getting it done more cheaply than by doing it themselves. What were Mr. Rowe's views on any possible development in that way, not necessarily applicable only to the British Corporations, but with a world-wide application?

He agreed on the importance of the greatest possible collaboration between the Industry and the operators, but it would help if the irregularities were confined to the schedules!

D. Atkins (B.O.A.C.): He had not heard before of the G.C.A. system being in use at La Guardia, where they still used the I.L.F. more frequently than anything else; and the one at Washington was used for emergency purposes only. It was a little difficult to accept the figures given for the use of the G.C.A.; and it seemed to him that they had nothing to learn from their American friends in the actual use of the G.C.A.

Whereas in Britain they were inclined to be polite, the Americans were slightly sceptical of the man who said "please" and "thank you." It seemed to be better, in airport control, to be *told* definitely what to do by an aircraft controller than merely to be *asked,* as they were in this country.

Could Mr. Rowe give an indication of the relative economies, for long-range flying, of using a large aeroplane carrying lots of people, or several aeroplanes, each carrying a smaller number, bearing in mind the problem of maintenance and also the handling of passengers? He had never heard the suggestion before about the Customs official going on board; it seemed an excellent idea, but perhaps it would be necessary to take a medical man and a migration man as well.

P. G. Masefield (Director-General of Long-Term Planning and Projects, Ministry of Civil Aviation, *Fellow*): Mr. Rowe had re-emphasised that they had still a long way to go before Air Transport became a really commercial business.

Dealing with the two problems which focused the theme of Mr. Rowe's paper—which was that they had to beat the low-visibility difficulty in operation—he first discussed Economy, and secondly, Speed; the two being inter-related. The more they looked at Air Transport the more they were convinced that *economy of operation* should be the major watchword, in the broadest sense of the term. He felt that economy was really the most significant factor of all. Surely the function of Air Transport should be to carry passengers and goods on a commercial basis, without imposing a burden on the taxpayer—however many Ministries had a finger in the pie. That need for economy had a bearing on both reliability and safety—indeed on all other aspects. Voicing what might be a slightly unpopular view, he thought that too much was heard about safety as such; safety was surely a part of the economic picture. There was a tendency nowadays to load up civil aviation with masses of expensive requirements, all directed at safety. These meticulous requirements would not kill passengers, but instead they might kill the whole business because nobody would be able to afford to fly at all. Obviously, they could not have absolute safety or absolute reliability if true economy were the objective. They could achieve only the amount of safety and reliability we could afford. Possibly, if they were really out for complete reliability and safety, they would not travel in aircraft at all, but would use television instead and keep their bodies on the ground. That would not achieve the desired end in, for instance, sending a cricket team to Australia, or for taking Mrs. Jones out to Mr. Jones in Calcutta. But if they were satisfied with a safety factor of 90 odd per cent.—which might mean that they would only kill one person in 20 or so million passenger miles — bookings would remain high (as on railways) because the public would not be killed frequently enough to frighten them. But if they strove for absolute safety, the costs in such things as landing aids would be so great that fares would rise enormously. To put the matter brutally, how safe was it worth being? If the safety factor were too low, so many passengers

would be killed that nobody would dare to travel by air. If too hign, nobody could afford to fly. The old law of supply and demand should provide the right answer on an economic basis.

On the question of speed, Mr. Rowe had indicated some of the problems of operating with present types of aircraft. They were, in all conscience, serious enough in conditions of low visibility. He was worried about the effect of turbine power plants on those problems. The turbine was relatively inflexible in the matter of consumption and in relation to heights and speeds. They could not "stack-up" a turbine. Yet at the Anglo-American Aeronautical Conference, in September last, person after person ignored this fundamental operating fact and had driven figurative nails into the coffin of the piston engine. The more he thought about Mr. Rowe's paper the more he was convinced that the turbine-engined aeroplane was at present economical only in good weather. And they could not afford a machine which was only useful in good weather. He predicted that it might take longer than had been thought to bring turbine aircraft into commercial aviation. But once that problem of turbines was beaten and they achieved the turbine's extra speed—bringing with it more revenue miles for a given aircraft utilisation per year—the turbine aircraft would be more effective and cheaper from the passengers' point of view. So that again focused attention on the main problem of low visibility operation.

W. Tye (Air Registration Board, *Fellow*): On the illustrations of the cancellations of aircraft caused by bad weather, what proportion was due to bad weather and icing conditions? He suspected that, in respect of the operations which B.E.A. conducted, probably a large proportion of cancellations was caused by forecasts of ice; but it would be interesting to know whether in these cases ice was actually present in the atmosphere, giving rise to danger, or whether the meteorological forecast indicated ice, the *actual* presence of dangerous ice being uncertain.

That led to a point where safety and economy could be balanced. If they could not rely on accurate meteorological forecasts, presumably they would have to build the best possible de-icing equipment for aeroplanes, at considerable expense in the aircraft design. On the other hand, if they could improve the meteorological facilities in order to obtain much more precise forecasts of what would, in fact, be encountered in the atmosphere, they could perhaps use less expensive and less heavy equipment on the aeroplane and could fly safely on a large proportion of the days of the year. Then they might balance the expense of those two aspects and decide whether it was better to put their money into the aircraft equipment or into improved meteorological facilities.

As to regulations, and in particular the influence of I.C.A.O. on regulations, the operator had to be provided with information as to the performance of the aircraft in different temperatures, pressures, winds, and so forth. The operator would then be required to comply with certain rules, whereby he had first to determine the information provided for the aeroplane, and to compare this with the particular routes along which he proposed to fly, thus judging the safe all-up weight of the aircraft. This procedure would be quite expensive. It would mean more testing of the aeroplane, more men in the operator's employ to do the necessary flight planning. Did Mr. Rowe think that would lead to more safety than the previous practice, which had depended far more on the general background of experience of individual pilots and, if it did lead to more safety, would it be very expensive safety?

S. J. Patmore (Consulting Engineer, *Associate*): Had Mr. Rowe, in considering the problem of airline operation from the maintenance engineer's angle, had experience of the statistical work involved in the application of the principles of quality control, the determination of periods during which components could operate satisfactorily, and the ultimate group replacement of various components, irrespective of their condition, at specific times?

S. Scott Hall (P.D.T.D. Ministry of Supply, *Fellow*): Operators had a serious responsibility to the Aircraft Industry in formulating and stating their requirements. The formulation of requirements was a difficult matter indeed. The operators, no doubt, were handicapped by not having long years of experience in forecasting, for that was what it amounted to; but it was obvious that, if they were to advance in civil aviation, a great deal more thought had to be given to this work by the operators. He suggested that there was a tendency to rely on the Ministries and the Industry to think up new ideas; but it was

only if the operators really played their part that they could get going. It was a long journey from thinking out the type of aeroplane to getting that aeroplane into service; if the thought did not come at the right time, then the aircraft was too late, or there was no production behind it, or there was some reason which would prevent it getting going. Even when they had a first-class aeroplane, there were many pitfalls in making it a first-class civil flying proposition.

Mr. Rowe had referred to the development of civil aircraft suitable for airline use; under present conditions, either they could have an aeroplane in which all the factors were well known and tried, with the result that when it came into operation on the airline it would be well behind that which their competitors might use, or they could have something advanced, but with the risk that it would be unsuccessful. Someone had to think out a way to ensure that the advanced type could be tried out and proved before going into airline service. It was largely a matter of money, and a difficult problem which would well repay study.

E. S. Calvert (Royal Aircraft Establishment): The two impressions left on his mind by the paper were, first, that the main problem before airline operators was that of maintaining regularity and second, that the chief factor in upsetting schedules was bad visibility. Mr. Rowe had mentioned that some work was now being done at the R.A.E. on high intensity approach and landing aids. He would confirm that and would add that judging from some tests which he had been making during the recent foggy weather, he now believed that this work would be more successful than had been expected. He felt that the visual aids had been seriously neglected until quite recently, but much work was now being done on them both in this country and in America. Indeed, the Americans now had an experimental station whose chief job at the moment was the assessment of various types of new high intensity aids.

Briefly the problem was as followed: when a pilot was making an approach in good visibility, he judged his height and distance by watching the pattern formed by the edges of the runway and the horizon. In bad visibility the whole of this pattern was blotted out and the question was then whether it was possible to substitute for it a pattern of lights in the approach zone, such that a pilot seeing a limited amount of this new pattern would know, first, whether the aircraft was undershooting or overshooting, second, whether the aircraft was correctly aligned with the runway, and third, whether the aircraft was banked. He was satisfied that all this information could be conveyed by means of a pattern which tests had now shown could be interpreted instantly and instinctively, particularly if the pilot were given preliminary training on a device which simulated what he would actually see in various densities of fog.

The question then arose as to what were the limiting conditions in which these high intensity aids could be relied upon to link up smoothly with existing radio approach aids. This could only be finally settled by the experience gained when the system had been installed on a busy airport, but from observations he had made from a captive balloon during the past week, he had no hesitation in saying that aircraft which had made an approach by radio down to 300 feet, could quite easily complete the approach and landing in the kind of weather they had been having that week, that was, in meteorological visibilities of the order of 500 yards. He had observed a full-scale installation of high intensity approach lights that morning, and had found that the range in daylight exceeded 2,000 feet. From tests made on the simulator, there seemed to be good hope that safe landings could be made if the lights could be seen at half this distance. He expected that in an aircraft with a reasonably good view ahead, it would be possible to make landings on the new "horizon bar" system in meteorological visibilities of the order of 200 yards in daylight and 100 yards at night.

Squadron Leader E. Coton (*Assoc. Fellow*) *contributed*: In 1939 a small unit responsible for the introduction of the Lorenz system into the R.A.F. considered that it would enable aircraft to land in conditions of 100 yards visibility, horizontally and vertically. Even if that estimate were optimistic, and they themselves bettered it, it was disappointing that, eight years later, they could not manage that with a reliability adequate for commercial use. Those who advocated the automatic system as the only sure solution, had, he thought, perceived one of the main reasons for this sorry state of affairs, which was that the characteristics of the pilot were not properly considered; now they were often assumed to constitute an insurmountable obstacle to a solution of the blind, or near blind, landing problem, the pilot therefore

having to be dispensed with altogether. One big difficulty which was always encountered in poor weather at low altitude was that the pilot, in order to retain control of his aircraft, must fasten his gaze on the instrument panel. Another was accurate control of the descent, for which the pilot must rely on the throttles; it was noticeable that automatic installations mostly left the throttles to the supposedly redundant pilot—a singular indication of the inadequacy of that particular control to play its part in a blind landing. It was quite clear that with the advent of turbines, something much more responsive would have to be provided to control the glide path.

He would like to suggest the adoption of a rather different approach and landing technique from that in use at the moment. Its aim would be to have the throttles fixed and to make the approach and hold-off at constant attitude. This was achieved by the use of a spoiler so designed that at constant attitude, the speed remained approximately constant; it would affect the lift of the wing raher more than the drag, and would, in consequence, be highly responsive. Such a control was, he believed, favoured for deck landing purposes. Attitude, air speed, and azimuth position relative to the localiser were now features which did not vary during approach and hold-off, and were thus admirably suited to control by automatics, or, as he would prefer it, by the second pilot, as in his experience pilots found it quite easy to follow a beam accurately if close attention to height were unnecessary. He might also have the assistance of G.C.A. monitoring. The first pilot, operating the spoiler, would be able to concentrate on controlling the descent and, if his height instruments were suitably placed, or G.C.A. monitoring were available, could keep a lookout as well. If he did not see the approach lights by the time he had reached the inner beacon, a blind landing could be effected merely by retracting the spoiler to give a rate of descent of less than, say, 10 feet per second.

This method of relieving the first pilot of the job of controlling the attitude of the aircraft by employing the second pilot, or the automatics, such as they were, was widely used in Bomber Command for the purpose of gaining visual, without physical, contact with the sea surface when the cloud was extremely low. One of the leading exponents was the late Wing Commander Guy Gibson. If the landing system were fully automatic, the installation would have to be considerably more complicated, and it would have to be accepted that a component failure would often be catastrophic. Components would have, in consequence, to become more reliable than would seem possible at the moment.

One point often overlooked in traffic control, was that an aircraft took about two minutes to get clear of the runway from a point on the approach at 200 feet, and two minutes was therefore the minimum landing interval if the runway were obscured to the aircraft following. If they then took an optimistic average of three minutes between landings, estimates of airport capacity in bad weather appeared to be rather optimistic, as Mr. Rowe pointed out. Further, if centre-line taxi lights were not provided to assist the aircraft on to the taxi track the two minute estimate would also prove optimistic.

From his own experience as a pilot and his contacts with Mr. Calvert's investigations into airfield lighting, he believed that an installation designed on the lines suggested by him would so reduce the incidence of effective zero-zero conditions that it would no longer be a matter of dire urgency to develop a blind touch-down technique.

H. M. March (*Associate*) *contributed*: One of Mr. Rowe's most important points was the fact that unless landings were achieved and the landing rate maintained with safety in bad visibility, all the vast planning programmes for aerodromes, landing rates and economics went by the board.

It appeared that Mr. Rowe had been thinking in terms of the scheduled operator, and as so often happened the weakest link in the chain had been left dangling to foil the main plan; this was the charter and private flyer who would not be able to afford the equipment necessitated by the control visualised, because of the cost or weight.

He believed that more thought should be given to this problem of the future, and hoped to see the number of private aircraft in the air over England far outnumber the commercial aeroplanes; now was the time to plan for this problem, as they might not in the future, be able to refuse these aircraft landing facilities at major airports.

He gained the impression during the first part of the paper that Mr. Rowe considered I.L.S. and S.B.A. far superior to the

G.C.A. approach. He had had considerable experience with most landing aids, especially the latter, and there was no doubt in his mind that the full possibilities of the G.C.A. approach had not yet been fully realised in either this country or in America. He was sure that it would be found by experience that safer landings with lower minima would be achieved by G.C.A. than any other aid visualised for a number of years to come, and that a landing rate of one per minute would be possible with certain modifications; this figure was more dependent on a system being evolved for clearing the runway for incoming traffic.

The following points should be taken into consideration with reference to G.C.A., especially from a user's point of view.

1. No distortion in the G.C.A. beam, already mentioned in the paper as affecting I.L.S. and S.B.A.
2. A steady approach path to the runway, with no bracketing of the beam.
3. No extra equipment in the aircraft other than extra R/T frequencies, therefore suitable for all types of aircraft, operator or private flyer.
4. Although the cost of the ground equipment and its operation and maintenance was expensive, this could be offset many times over, when the comparative cost to civil aviation of the ground equipment, maintenance and individual aircraft equipment was taken into consideration for other aids, on a national or world-wide basis.
5. A pilot was continually informed of his distance from touchdown, and his position in relation to the glide path.
6. There was less strain on the pilot, and G.C.A. allowed a tired pilot to concentrate on his instrument panel and landing.
7. Landings could be undertaken in safety with lower visibility and cloud base than other aids.
8. Given the frequencies, a steady landing rate of 20 to 24 per hour could be achieved on one runway now, with a landing rate of 60 per hour possible on one runway in the future.

The development in high intensity lighting was interesting, but care was needed when applying this aid to taxi tracks during bad visibility conditions, because it had been known for pilots to mistake taxi tracks for runways and either land on them, or turn sharply towards them by mistake; this should be carefully considered from a safety point of view.

Mr. Rowe had said that ultimate economy was dependent on the all-up weight of the aircraft per passenger, but he would like to suggest that further consideration should be given in this country to the development of lighter-than-air craft.

It was useless for I.C.A.O. and I.A.T.A. to lay down general safety standards, unless the countries and operators concerned realised that to achieve the desired safety they must accept the ultimate expense, control, equipment and the resultant weight in the aircraft.

F. A. Roberts (Chief Engineer Aerlinte Eireann) *contributed*: He would like the author's comments on the following:—

(a) What were Mr. Rowe's views on the future types of civil aircraft in relation to all-up weights? Was he of the opinion that increases on civil airlines to a maximum of 150,000 lb. weight were likely to be exceeded?

This rather important point required consideration from two aspects:

(i) Existing aerodromes which, because of wartime expansion, had placed civil aviation in the position of operating aircraft at the present all-up weights and were probably capable of receiving aircraft up to a maximum of 150,000 lb.

Did Mr. Rowe think that to go beyond the above maximum all-up weight, problems were going to be faced in connection with landing weights of aircraft and increased runway length? Was it his opinion that this was going to affect the economical operation of larger types of civil aircraft?

If they were going to limit maximum all-up weight and utilise more aircraft, would more aerodromes around the larger type of towns throughout the world have to be created?

(ii) The expansion of aerodrome facilities to meet future demands was a matter which might have to receive immediate consideration, and he would like Mr. Rowe's views on this point as the question of economical operation, the minimising of holing and stacking, would appear to be major problems.

(b) With regard to the improvement in navigational aids discussed during the lecture, did Mr. Rowe think that present aids had

reached their limit so far as their application was concerned, or was further development to improve existing aids possible?

He thought that to add more equipment to the already over-equipped cockpits would approach the stage where it would become an impossibility for the average airline pilot capacity to operate efficiently, taking into account the duplication and, in some cases, triplication, of instruments to meet safety requirements.

Did Mr. Rowe think that the introduction of jet type aircraft into civil aviation was going to limit operation of civil aircraft to the almost ideal weather conditions, thereby cutting down utilisation figures to an absolute minimum?

K. G. Wilkinson (British European Airways, *Assoc. Fellow*) *contributed*: There were four main question groups to which an operator required answers on any component of an aircraft, whether it were a turbine or a tailwheel.

(a) What did it weigh as installed ready to perform its function on the aircraft?
(b) How much did it cost to maintain and what was its life?
(c) How did it affect performance (by its influence on drag, propulsive efficiency, permissible flying weight, and so on)?
(d) What was its first cost?

Each function performed on the aircraft could be done in a number of ways, but until those questions had been answered it was usually impossible to say which way was best. Answers to (b) and (d) were commonly the most difficult to get, but unfortunately a choice made neglecting these features could easily be the wrong one.

Propeller turbine engines were an important instance where such a choice had to be made. Mr. Masefield commented on the adverse effect of fuel allowance for stacking on the attractiveness of turbines for civil operations. This was only a part of the picture and the final outcome depended very much on the answers to (b) and (d), and on the part played by actual installation weight in (a). If installation weights were low, then for a typical medium range operation of about 500 nautical miles the turbine was competitive, in spite of high fuel reserves (which it was hoped were a passing phase) provided that answers to (b) and (d) were not appreciably worse than for reciprocating engines.

So far as the commercial operator was concerned, therefore, a great deal depended on getting reliable estimates of (b). At present it did not appear possible to make such estimates and a necessary first step to putting propeller turbines into civil operation was to carry development to the stage where a forecast could be made. Not until then would the regularity and economy, which the lecturer rightly stressed, be sufficiently calculable to enable the choice to be made with reasonable risk.

The assumption that hourly costs and fixed charges varied as all-up weight, might not give a satisfactory approximation. In fact, a great deal of the cost involved in operation was incurred by inspecting and servicing items of equipment which need not get vastly more numerous or complex as the aircraft size increased. For example, the radio equipment needed for European operations would be the same for a wide range of aircraft size; engine maintenance was appreciably affected by the actual number of parts which had to be removed, inspected or repaired, and an aircraft with two 3,000 h.p. engines would not necessarily require ten times the maintenance man hours required by an aircraft with two 300 h.p. engines. Similar arguments applied to power services and many other parts of the aircraft; indeed, by careful design it might be possible to beat the "Cost proportional to weight" law quite handsomely.

A. H. Stratford (British European Airways, *Assoc. Fellow*) *contributed*: The problems of air transport could be divided into those within the spheres of technics, politics and economics. While the first was in process of solution by science and industry, as described by the lecturer, and the second had no final solution, the linked problems of technics and economics were receiving insufficient attention and were in danger of being approached by the newest of transport industries in a railway age manner.

Various criteria had been suggested for the assessment of the economic value of transport aircraft, but none could be of absolute value as a guide to economy of operation, because of the fundamental variable which was the organisation and operational efficiency of the individual airline concerned.

In the United States of America, where the airline business had reached high levels of efficiency, the ratio of indirect to direct operating costs for the domestic industry in

1946 was close to 1.5, and during the war years was considerably higher. Direct operating costs, and essentials dependent on operational performance of aircraft, could not therefore be claimed the only indices of economy and the engineer/economist must watch the trends of other criteria.

The aeroplane as a transport vehicle was unique in its high direct cost of operation, due in great measure to (a) the short life of components, and (b) the high cost of materials and skilled labour. Further, there was for any aircraft an optimum non-stop distance for maximum earning capacity which was to be ignored only with dire penalty for the operator. Unfortunately, a multiplicity of operating types could only result in increased costs in items (a) and (b) above, so that one solution lay in an aggressive onslaught with intensive service and advertising on profitable routes with aircraft of the highest earning capacity.

It was probably safe to say that for any transport aircraft now flying, there was a route within the European region on which it could be operated with a reasonable surplus on year-round service.

The broader question as to what characteristics were required by an aircraft to achieve a profitable operating result on a chosen route system, had not received, up to now, the attention that it deserved. The right solution would require conjoint efforts in technics and economics.

MR. ROWE'S REPLY

Sir Conrad Collier: The inter-linking of agencies, the close team work needed and the extreme importance of being well represented on I.C.A.O. were of great significance, not only to operators, but in the national interest as well.

He felt it would certainly be necessary to provide a place at which to practice new techniques in air traffic control; it might be necessary to set aside an airfield for that purpose. But the first matter in air traffic control was to make what might be called a laboratory assessment, a mathematical and physical matter, in order to find the best method, because he did not think they knew it at the moment.

Professor Hall: Professor Hall's reference to the effects of the random arrival of aircraft, was extremely interesting. His figures seemed to emphasise clearly the need for such means of navigation *en route* as would give accurate definition of position in space at all times, and so permit of a regular schedule of aircraft at all points of their flight. Randomness in arrival at the airport would then arise only out of irregularities *en route* or delays in the control area.

With regard to the optimism or pessimism of meteorological forecasting, enquiry had not elicited very precise information, since there had not been a steady collection of comparative data between "actuals" and "forecasts" over an extended period. Quick checks were made from time to time; the conclusion from these was that the accuracy for aviation purposes was high, and that in the inaccurate cases there was no pronounced trend towards pessimism in forecasting.

With regard to omni-directional range and GEE, he had merely stated that it was claimed for them that they would give the facility he had indicated. He had no experience of omni-directional range, and did not think it was in use much. GEE was in use, in Vikings on B.E.A. routes, and they were now finding out exactly what degree of precision the navigators were achieving. Extensive tests had been made during the war which showed that, with GEE, navigation error varied with range, with position in the "GEE coverage," with conditions as affecting signal strength, and so on, and with crew. The error referred to here was the 50 per cent. probability error. In reasonably good conditions this was about $\pm\frac{1}{4}$ mile in range at 50 miles from the stations, and could be taken to vary with range. The error in azimuth was less, the ratio depending on range and position in the "coverage." Accuracy of this order in *en route* navigation should greatly facilitate orderly, as distinct from random, arrival at airports.

He agreed entirely about the elapsed time being important to passengers; the reduction of the time lost because of customs and immigration formalities was one of the factors they had to work at steadily in order to obtain improvement. This was more a political than a technical matter in its broader aspects.

They must look forward to short-stage flying at such frequencies that passengers could come to the airports and go aboard aircraft without having pre-booked.

Mr. Kaiser: He agreed that research was needed on methods of establishing the length of life of components, so that proper flow

arrangements for components could be maintained. Without that there would always be uncertainty in connection with the maintenance of aircraft, giving rise to irregularity in running at high maintenance cost. However, it was a difficult problem to tackle "in the field," since precise measurements were needed; probably a laboratory approach would be best initially.

The point made by Mr. Kaiser concerning research on the functional design of hangars was a good one, although perhaps somewhat unrealistic in the present state of building in this country. The "dock" system had obvious advantages and should be used if at all possible.

Mr. Edwards: He thought he had been more kindly to designers than had Mr. Bain. Unfortunately Mr. Bain was not present to give support.

He agreed that the picture seen in the crystal formerly was not the picture they saw to-day; but the blame could not be placed entirely on the operators or on those who had been optimistic about turbine engines. He felt that, in Europe at any rate, much of the difficulty was caused by the general unsettled conditions; their expectations of really good ground aids in all countries in which they wished to operate, of reasonable airfield facilities, and so on, had not been realised, whereas they might reasonably have expected that they would have been available by now. Those things had the strongest repercussions on the aircraft and its economy, because their absence meant that very much more reserve fuel had to be carried; that had a specially marked effect on turbine-engined aircraft, much more so than on reciprocating-engined aircraft.

He had expected comments on the heavy responsibility borne by operators in advising designers; he felt it was right that the operators must recognise that responsibility and must do what was necessary in their organisations, their recruitment, and so on, to discharge it, for otherwise he believed they would not get the right aeroplanes at the right time. Nevertheless, the difficulties were great because of the time scale and because of the development problem, referred to by Mr. Scott Hall. They must look for assistance from all concerned and a little mercy from time to time, because the guesses might be wrong.

It was important that, in legislating for new types for civil, as distinct from military, operation they must ensure that the aircraft that came forward must be ready for full operational use with a high standard of reliability, because they would replace aircraft which were already working effectively and giving public service. The civil airline operator must be quite sure that he would get what he asked for at the right time, for otherwise all his plans would go wrong. Civil aviation was very different from military, especially in peace-time, when there was time for further development in military aviation and, if necessary, for the rejection of aircraft altogether.

Referring to the question of sub-contracting major maintenance, he thought that a great deal would depend on the size of the fleet, the number of types and the complexity of the maintenance operation. If the conditions were such that the major maintenance could be handled on a production line basis then, provided that dead flying was small, the method of sub-contracting might be advantageous.

Mr. Atkins: He believed that the figures he had given for the use of the G.C.A. by the Americans referred, possibly not to regular operation, but to extended trials of the equipment, especially the combined use of the I.L.S. and the G.C.A. He had obtained the figures from Mr. T. P. Wright, and he believed they were really representative.

With regard to the relative economies of operating one large aircraft and a number of smaller aircraft over long ranges, assessment was difficult without knowing details of the area of operation, the particular route, and so on, because so much depended on the frequency demanded. If the frequency demanded were high and the traffic density were low, the use of rather small aircraft might be necessary; but if the frequency were not high and if the traffic were suitable, the use of one large aircraft might be better. In general he would expect the large aircraft to be more economical than the small ones.

Mr. Masefield: Although Mr. Masefield expressed the view that economy of operation, in the broadest sense, was the basic factor to bear in mind in connection with commercial flying, he still felt that the development of an aircraft which would be able to give high regularity and punctuality was the primary need, because unless those conditions were met—and he had suggested a 98 per cent. factor—the public would not travel by air; if they wanted to be quite sure

of reaching their destinations at appointed times, they would travel by other means. But that objective carried others with it; if they could secure the aids he had mentioned, then probably their standard of regularity would be greater.

He agreed that there was no absolute standard of safety and reliability, unless the aircraft sat on the ground all the time—and then it would not carry passengers very far! But once they had arrived at a compromise, it was necessary to make a very close study of the economy that could be attained with the standards of safety that were necessary.

As to turbines *versus* reciprocating engines, bearing in mind the conditions in Europe and the prospect of those unsuitable conditions remaining for some time, he agreed that if they wanted to be certain of having something which worked, with the airfield conditions, ground aids, and so on that were likely to exist, the reciprocating engine was probably the right thing to use.

The problem of speed and revenue depended very much on whether the traffic in a given area would carry the increased frequency that must go with increased speed. If it were decided that a certain utilisation per annum was necessary for economy, and if then the speed increased, that increased speed could only be used at the same utilisation if the frequency of operation were correspondingly raised; if people did not use fully the aircraft which gave the higher frequency, the operators might not achieve the economy they had thought they would achieve from the higher speed. So that very much depended on a complete study of the whole area.

Mr. Tye: The best information he had been able to get in reply to the question about icing, was that cancellations of B.E.A. services, because of fog or ice in the London area, were in the ratio of about 2 to 1 from these causes respectively. As to whether they should go in for the best de-icing equipment in the aircraft or for better forecasting, he believed they must have the best de-icing; and whatever the forecasting, if the ground aids were not so good that the aircraft could depend on coming right in without any waiting, the aircraft might be forced to fly around in ice while waiting to come into the airfield, and if it iced up under those conditions it might have very serious trouble when it did come in to land.

As to the effect of I.C.A.O. on safety, whether the tying down of the operator, provided that he obtained the right information from I.C.A.O., would lead to more or less safety, he was not sure, but he felt it was likely to lead to less economy without very much increase of safety. It was better to have reliability and allow operation to standards which would give safety, with the information given to the operator.

Mr. Patmore: The whole problem of maintenance was one they did not understand very well, and he suggested that Mr. Kaiser's reference to research and development with a view to deciding the life of components would provide the answer.

Mr. Scott Hall: He did realise that there were great difficulties and that operators had serious responsibility. Civil aviation was still in the development stage, despite all the background in the United States. A very great deal of the operation there had been done with one type of aeroplane, the DC-3, and immediately new types of aircraft were introduced into a given area troubles began.

He would not agree that there was a tendency to rely on the Ministries for all the good ideas.

He agreed that it was necessary to obtain the right types of aircraft at the right time; but it was difficult sometimes.

Mr. Calvert: He had seen Mr. Calvert's arrangement of high intensity lighting, and so on, and was extremely impressed by it; anyone who was interested ought to make sure of seeing it, because high intensity lighting in conditions of low visibility was important. If, as Mr. Calvert had claimed, it was visible from 2,000 ft. in a fog such as had been experienced that morning, it took them a long way towards the answer to their problem. It was particularly valuable because it was on the ground; it was also reasonably cheap, and did not entail the installation of a lot of highly developed equipment in aircraft; the installation of the latter might be possible for some operators, but some time must elapse before some operators and nations could adopt it, and while some aircraft were still without it, irregularity and unpunctuality would persist.

Squadron Leader Coton: Squadron Leader Coton did not favour the automatic pilot for blind landings, but his own view was stated in the lecture, namely, devise aids to facilitate approach in all conditions with full safety and allow the pilot to make the critical final manœuvre of landing, aiding him as necessary by lighting or FIDO or other aids. He was not sure that the spoiler control advocated

by Squadron Leader Coton would effect the improvement he expected. If he meant what he said, that flight speed was to be kept constant in the approach, then the flight path, in space, would vary with wind strength, which surely would not do. In this respect he thought the deck landing problem was quite different.

A very real point had been made in the comment on traffic control and the importance of aids for taxying to ensure that runways were cleared without delay. Taxi lights seemed to be the best solution at this stage.

Mr. March: The implication in the reference to charter and private flying seemed to be that as much as possible of the low visibility aids to approach and landing should be on the ground. He agreed with this, as a principle, provided that it did not involve unduly expensive equipment, training and manpower, and promoted the maximum utilisation of major airports by the main users.

Mr. March's views on G.C.A. were most interesting; he held no brief for I.L.S. and S.B.A. In the text of the paper he stated what he considered to be the broad underlying principle of air traffic control, *i.e.* the promotion of maximum overall economy. The time for clearing the runway might be, as Mr. March said, the final criterion of landing rate; it was therefore of great importance to develop the best aids to taxying in low visibility conditions.

Mr. Roberts: He understood the question (a) to apply to short and medium stage distances, say 800-2,000 nautical miles.

To judge from past experience, the payload capacity of the unit would steadily increase, *e.g.* the use of the DC-4 and projected widespread use of Martin 202 and Convair for systems previously operated by DC-3. Taking a broad average, the number of seats/aircraft in operation in U.S.A. domestic airlines increased about fourfold between 1932 and 1946. The curve showed no abatement in the rate of increase. A continuance of this trend would result in steadily increasing the all-up weight of aircraft operating given route systems. Increased cruising speeds would probably lead to expansions of route systems in the direction of more non-stop runs, such as the trans-continental system now being actively developed in U.S.A. This type of operation would naturally force development of large aircraft; hence, depending on the route system, he expected the figure of 150,000 lb. all-up weight to be exceeded within ten to fifteen years.

He thought they would need new airfields. He also suspected that existing airfields might be found, in many cases, susceptible of comparatively simple development to take high overloads. Hard standings might be the worst problem at these overloads.

In reply to (a) (ii), the true capacity of an airfield in relation to reliable operation, *i.e.* regular, punctual operation, was its capacity in I.F.R. conditions. In his view the most immediate contribution towards increasing this capacity was likely to be efficient approach runway and taxi way lighting, such as proposed in the R.A.E. scheme.

With regard to navigational aids, which he took to include short- and long-range aids, he thought they could look for improvement in some of the existing aids, but agreed that they must aim to simplify cockpits and not only by reducing the amount of equipment to be operated, but also by a new approach to lay-out, with special reference to the critical operations of blind flying and blind approach.

He thought that jet propulsion would not be used for civil aviation if it entailed the strict limitation to fair weather suggested. But there was no reason for such limitation, provided that navigational approach and landing aids were developed to avoid holding at airports, and that they operated at reasonably low speeds in rough air.

Mr. Stratford: He agreed generally with his remarks. The problem of aircraft types for a route system was the real one facing the operator. It was the problem of serving the system efficiently with the minimum number of types for all purposes, passenger, mail, cargo. Its solution involved compromise; but fundamentally no realistic solution was possible without accurate forecasting of the economic future, the trends of industry and business. Unless the engineer had good information from the economist he could not be expected to specify the best aircraft for a given route system.

Mr. Wilkinson: The question groups were well chosen. In addition, he thought the operator must be assured of the reliability of the component, since one of the worst enemies of planned maintenance was the random failure, due primarily to lack of development. This was borne out by Mr. Wilkinson's own remarks about the propeller

turbine. He thought they were faced with a very difficult problem in the rapid development of turbine engines to an acceptable standard of reliability for civil air transport operation. They would not get such engines into use in a reasonable time if they waited to build up the background of experience in actual use, since that could only be done in military aircraft, and would take a long time under present conditions. He was sure they must develop a new technique of accelerated tests to give them the information needed; a parallel example was the accelerated corrosion testing technique which proved such a valuable tool in the development of aluminium alloys.

He was in general agreement with the comments in the final paragraph of Mr. Wilkinson's remarks, but the formula he adduced was intended to apply to aircraft in a given class in which wide variation in the factors he mentioned would be unlikely.

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THE PRODUCTION OF LIFT INDEPENDENTLY OF INCIDENCE

A Review of the Principles of the Thwaites Flap, of the Design of suitable Aerofoils and of some experimental results

by

BRIAN THWAITES

Mr. Thwaites, who was a Wrangler in 1944, *left Cambridge to join the Low-Drag Group at the National Physical Laboratory. During his three years there he contributed to the knowledge of aerofoil design and to boundary-layer theory, in which he has specialised. Since October* 1947 *he has been a lecturer in the Aeronautics Department at the Imperial College.*

INTRODUCTION.

IN the past few years, two problems in applied aerodynamics have received much attention. The first is the problem of low drag in which it is desired to reduce considerably the drag of aerofoils over a certain range of lift coefficient by suitable design and construction. The second is the problem of increasing the lift in which it is desired principally to obtain a higher maximum lift coefficient.

The low drag problem is satisfactorily solved in the case of fairly thin aerofoils by the maintenance of an extensive region of laminar boundary-layer flow over the aerofoil's surface, and the relevant criterion of the pressure decreasing along the surface is now well known. For thick aerofoils (say, of 25 per cent. thickness and more) separation of flow must first be prevented for a reduction of drag and this may be achieved by any one of various methods of boundary-layer control.

The usual solution to the maximum-lift problem has been the use of flaps, but the demand is for still greater max. C_L's. There are two general possibilities: the first is to ensure that the lift increases with incidence beyond the normal stalling point, and the second is to increase the lift at a given incidence above the Kutta-Joukowski value. Both these methods appear to demand the use of boundary-layer control in some form.

In this paper a method will be described which, in a sense, provides a solution, at any rate for thick aerofoils, to both these problems at once. It will be shown how lift may be obtained without a corresponding incidence by using a type of flap which moves around a well-rounded trailing edge through which continuous suction is applied. A discussion of the device may be found in Reference 1.

In this way, it is possible to double the range of C_L's for which laminar flow is obtainable, and to obtain high C_L's. These results are possible for any fixed incidence, and thus the embarrassment of high angles of incidence is avoided. Aerofoils fitted with this flap have several other interesting properties which will be explained below. Clearly, proper design of such aerofoils is just as necessary for good results as with ordinary low-drag aerofoils.

1. FUNDAMENTAL IDEA.

Consider the two-dimensional flow of a uniform stream past an aerofoil. The well-known Kutta-Joukowski hypothesis states that the strength of circulation about an aerofoil is such that the velocity in potential flow at the trailing edge is finite.

The accuracy of this hypothesis improves in general with the sharpness of the trailing edge and, in fact, aerofoils are designed with sharp trailing edges so that the degree of dependence of lift on incidence is as great as possible.

Suppose that for a certain aerofoil this correspondence between circulation and incidence is not required. Then in potential flow, the rear stagnation point is not situated at a fixed point. No singularity may occur either outside or on the aerofoil's surface, for at such a point a condition is imposed by the

steady flow of real fluid. Thus the aerofoil may have no sharp edges or cusps on its surface and indeed, should be well-rounded, especially near the trailing edge. We now suppose that continuous suction* is applied over parts of the aerofoil's surface in such a way that separation of flow is entirely prevented. It may be found desirable after experimental investigation that not only separation be prevented, but that the boundary-layer thickness everywhere be less than a certain length. Under these circumstances a potential flow can be found to represent closely the real fluid flow if the circulation is known. The converse problem is to produce a flow with circulation about the aerofoil to correspond to a calculated potential flow.

If a potential flow is calculated about an aerofoil (in which the circulation chosen is arbitrary†) the dividing streamlines are known. In the real fluid, let a thin solid boundary or flap be placed along the calculated rear dividing streamline to extend from the aerofoil's surface to a certain point downstream. The hypothesis is then made that the steady flow of real fluid past the aerofoil will approximate closely to the calculated potential flow with the circulation.

Let us examine the process by which this circulation is obtained. The two most interesting cases are when (a) the flow is started from rest with the flap in position and (b) the flap is moved from one position to another. Consider, for simplicity, a circular cylinder—for flow about a circular cylinder the dividing streamlines are almost straight and normal to the surface for a distance of half a radius from the surface, at any rate for small lift-coefficients, say for $C_L < 4$.

If the flow starts from rest with the flap deflected and continuous suction suitably applied, potential flow without circulation will occur initially in which there is a stagnation point on one of the flap's surfaces and a very large velocity round the edge of the flap. A vortex is soon formed near the end of the flap which is carried downstream, thus leaving a certain circulation about the cylinder. The flow continually adjusts itself in this way, vorticity being carried downstream at a certain rate with the circulation being changed correspondingly, until a steady state is reached. This steady state will occur when the velocity at the end of the flap is finite, which will correspond to the potential flow of which the flap is part of the rear dividing streamline. In this way the calculated circulation is set up.

Similar mechanism applies when in uniform flow the flap is moved to a new position. When a steady state is reached, a movement of the flap will result immediately in a stagnation point on the surface of the flap and a very high velocity round its end. A vortex will form and be carried downstream causing a change in circulation and again the flow will adjust itself until the velocity at the end of the flap is finite and the total rate at which vorticity is carried downstream is zero.

These physical happenings are illustrated in Figs. 1 and 2.

We have seen how any circulation* may be obtained for an aerofoil at a given incidence in a uniform stream. The only requirements are continuous suction to prevent separation of flow, a well-rounded shape and a suitably shaped and placed flap. Aerofoils using this principle possess some curious properties and possibilities which can be exploited most fully by good design, and we will now deal with such considerations.

2. PROPERTIES, POSSIBILITIES AND DESIGN OF SUCH AEROFOILS.

Some results concerning the aerodynamic behaviour of such aerofoils will first be quoted. Their derivation appears in reference 2. For an ordinary aerofoil whose C_L is (approximately) proportional to the incidence, the centre of pressure is near the quarter chord point and is fixed only if the moment at zero C_L is zero. The moment varies with C_L, or incidence, also.

One of the more obvious advantages of the independence of incidence and circulation is the ability to use an aerofoil at a constant incidence, variations in C_L being obtained by movement of the flap. We will therefore consider for the moment an aerofoil which has a constant incidence to the stream. For such an aerofoil it can be shown that neither the moment coefficient nor the line of action of

*In this type of boundary-layer control, a porous surface is used for which the size and spacing of the pores are small in comparison with boundary-layer thickness. Air is then withdrawn continuously from the boundary-layer through the surface.

†We must impose the restriction on the magnitude of circulation that there shall be two (or at least one) stagnation points on the surface.

*With the restriction given in the † footnote opposite.

the lift force varies with the lift coefficient. In general for such an aerofoil, the line of action of the lift force may pass through any point of the chord. However, for an aerofoil which is both symmetrical and at zero incidence, the moment coefficient is always zero and the line of action of the lift force passes near the mid-chord point. For a doubly-symmetrical aerofoil, $C_M = 0$ and the lift force acts through the mid-chord point. Use of such an aerofoil would therefore involve very simple control problems.

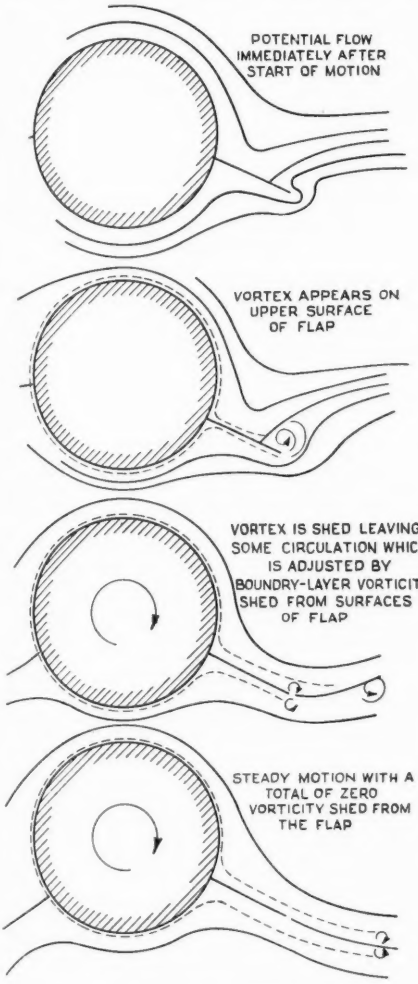

POTENTIAL FLOW IMMEDIATELY AFTER START OF MOTION
VORTEX APPEARS ON UPPER SURFACE OF FLAP
VORTEX IS SHED LEAVING SOME CIRCULATION WHICH IS ADJUSTED BY BOUNDRY-LAYER VORTICITY SHED FROM SURFACES OF FLAP
STEADY MOTION WITH A TOTAL OF ZERO VORTICITY SHED FROM THE FLAP
STREAMLINES
EDGE OF BOUNDARY-LAYER
VORTICITY
DIAGRAMS NOT TO SCALE

Fig. 1.

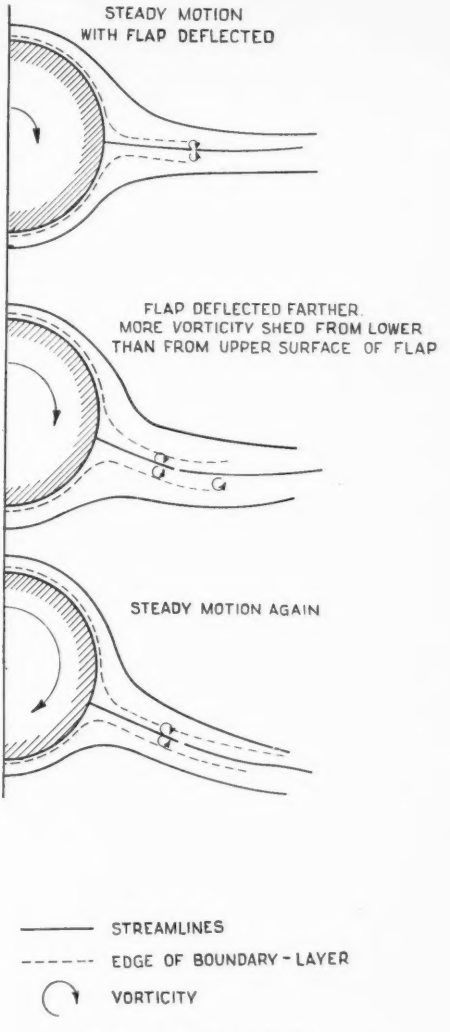

STEADY MOTION WITH FLAP DEFLECTED
FLAP DEFLECTED FARTHER. MORE VORTICITY SHED FROM LOWER THAN FROM UPPER SURFACE OF FLAP
STEADY MOTION AGAIN
STREAMLINES
EDGE OF BOUNDARY-LAYER
VORTICITY
DIAGRAMS NOT TO SCALE

Fig. 2.

Consider now the requirements in design of aerofoils to be used with the flap. The ability to obtain lift independently of incidence renders change of incidence unnecessary (except possibly in a case which will be mentioned later) and we can restrict ourselves immediately to the case of zero

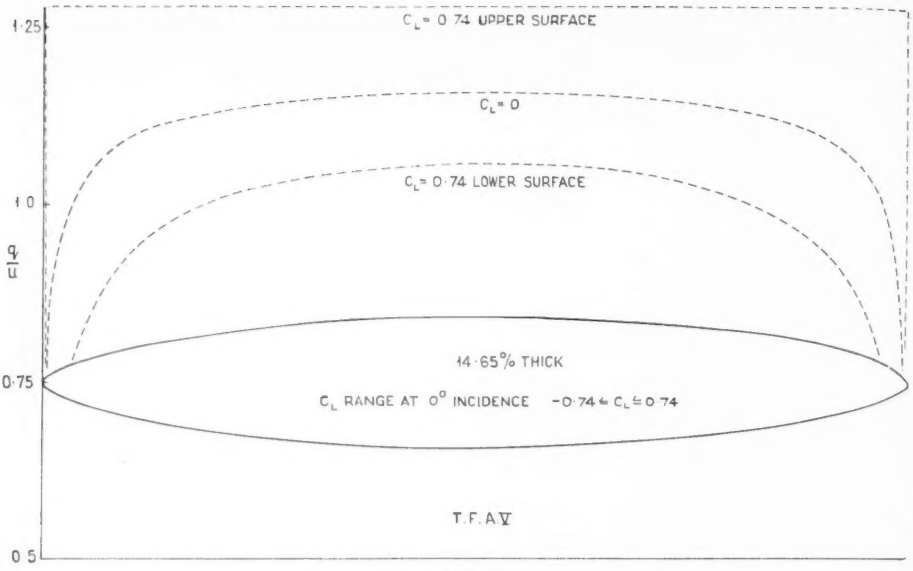


Fig. 3.

incidence. First, the extent and amount of continuous suction should be minimised and this can be accomplished for a range of C_L's by ensuring laminar flow over as great a part of the surface as possible. Elsewhere, where the pressure rises suction will be applied. This requirement is thus very similar to the ordinary low-drag requirement for conventional aerofoils, and is satisfied by decreasing pressures over a large part of the surface for a range of C_L's.

In the design of ordinary low-drag aerofoils, it is usual to design so that the velocity at the top of the C_L range is constant over the front part of the upper surface. Over the rear part it will, of course, decrease to the trailing edge. For aerofoils to be used with the flap, we can go further and postulate a constant velocity over the *whole* of the upper surface at a certain lift-coefficient.* Below this C_L, the velocity will increase up to mid-chord then decrease. Above this C_L, the velocity will have a sharp maximum near the leading edge, decrease and increase again to a maximum near the trailing edge. The velocity on the lower surface for $C_L > 0$ will have a maximum at mid-chord. The extent of continuous suction required in this example would appear to be the rear half of the aerofoil's surface. This area of suction could be decreased by designing the aerofoil to have falling pressures for a range of C_L's over, say, 70 per cent. of the chord. This, however, would result in an aerofoil having its maximum thickness and centre of pressure behind mid-chord, although C_M would be zero. For this type of aerofoil flying at zero incidence, the C_L range, or laminar flow range, is approximately double that for an ordinary aerofoil of similar thickness, which alone would make possible considerably improved performance.

Another advantage in using an aerofoil at zero incidence is that the maximum velocity for a certain C_L and thickness is less than that for an ordinary aerofoil in similar circumstances. Thus it is probable that a higher critical Mach number can be obtained by use of such an aerofoil.

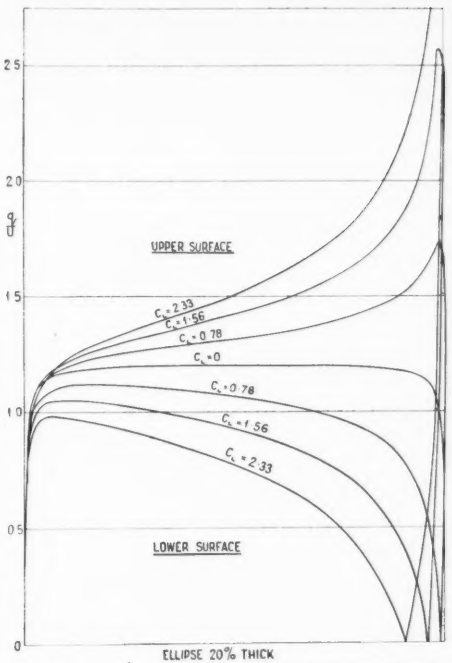
Figure 3 displays the doubly symmetrical aerofoil T.F.A. V of 14.65 per cent. thickness which has a C_L range of $-.74 \leqslant C_L \leqslant .74$, and for which the velocity on the upper surface equals 1.27 at $C_L = .74$. This example of a thin aerofoil is given to facilitate comparison with similar ordinary aerofoils. It may be, however, that the practical advantages of using the flap increase with the thickness

*An interesting theorem states that it is impossible for the velocity to increase over the *whole* upper surface, although a constant velocity is possible.

(providing there are no adverse effects from compressibility), and it should be pointed out that aerofoils similar to T.F.A. V can be designed for any thickness. For instance, for one of 53 per cent. thickness, the C_L range is $-7.8 \leqslant C_L \leqslant 7.8$ which is very large.

The behaviour of these aerofoils at very high lift must be considered. As the C_L is increased above the top of the C_L range at zero incidence, the velocity maximum near the leading edge will increase and eventually separation will occur near the leading edge of which the final effect will be the stall, in which further deflection of the flap will produce no increase of lift. This state of affairs may be avoided by decreasing the incidence in a suitable way outside the zero-incidence C_L range. Suppose, for example, that the incidence is decreased so that the leading edge is always at stagnation point. Then the velocity will always increase over the front part of the aerofoil and large adverse velocity gradients will not occur, except near the trailing edge at which the continuous suction will prevent separation. Thus the usual stalling characteristics will have been avoided and very high C_L's would appear to be possible. Furthermore, the embarrassment caused by the high incidences of some modern aircraft on landing is entirely avoided: indeed the pilot would obtain an excellent view of the ground! The argument can be followed easily from Fig. 4 which demonstrates the velocity distribution over an ellipse whose incidence is decreased as the C_L increases.

It is possible that the flap may provide a solution to another problem that has recently become important. When a large aircraft flies into a gust of wind the sudden change in lift may be too great for the aircraft frame to withstand. The solution is being sought in a form of control which will keep the C_L constant throughout a change of incidence. Consider a wholly rounded aerofoil provided with continuous suction to prevent separation with a certain circulation in a uniform stream. Then a change of incidence will not be accompanied by a change in circulation. The gust problem is therefore reduced to that of setting up near-potential flow with circulation about a rounded aerofoil. This can be done by using the flap in the ordinary way so that the required circulation is set up and then by withdrawing wholly the flap into a slit in the aerofoil so that the circulation is unchanged during withdrawal. A rounded aerofoil is thus left with a certain circulation which will not change with incidence.



VELOCITY DISTRIBUTION FOR VARIOUS C_L'S WHEN LEADING EDGE IS A STAGNATION POINT

Fig. 4.

Finally, we must examine the forces acting on the flap. In steady flow, since the flap is thin, the velocity of fluid will be equal at corresponding points on either side and therefore the force on the flap is zero. When the setting of the flap is altered, a force must be applied to it until the appropriate amount of vorticity is shed and once again steady flow exists. No examination has been made of the stability of the flap when it is left free to move about the equilibrium of a certain steady flow. If it is stable, then another solution of the gust problem presents itself in which an unrestrained flap will, during changes of incidence, adjust its position automatically to ensure a minimum amount of asymmetry in the flow past it and hence, a minimum change in circulation.

3. EXPERIMENTAL WORK.

The flap was first fitted to a completely porous cylinder. The cylinder was made of Porosint* material Grade C and is $1\frac{1}{2}$ in. in

*Made by Sintered Products Ltd., Sutton-in-Ashfield, Nottinghamshire.

diameter and 6 in. span. It is fitted between false walls in a square working section. A single pressure hole was fitted in the surface which could be placed at any angular position by rotation of the whole cylinder. The straight flap was $\frac{3}{8}$ in. long and could be rotated, normal to the surface, about the centre line of the cylinder. The range of deflection was about ± 40 degrees about the zero C_L position.

The amount of suction applied, given by $C_Q R^{\frac{1}{2}} = 62$†, was sufficient to reduce to zero the total head loss behind the cylinder. This quantity is, of course, much greater than is required to obtain a wake drag coefficient comparable to that of a thin low drag aerofoil. If a rough criterion to determine when separation occurs is used, the quantity required to prevent separation of flow was found to be given by $C_Q R^{\frac{1}{2}} = 13.7$ which is a value very close to various theoretical predictions. This is most encouraging for it gives experimental verification to theoretical results concerning continuous suction which thereby is shown to be more economical than suction at a slot.

The pressure distribution was measured on the cylinder for some low angles of flap deflection, and the C_L estimated for greater deflections by measuring the minimum pressures on the upper and lower surfaces. In Fig. 5, a typical velocity distribution is shown graphically; here, the flap deflection is 10°. The theoretical distribution for the same deflection in an infinite stream is drawn and it is remarkable that the experimental curve lies so closely to the theoretical curve. In Fig. 6 the experimental lift curve is compared with the theoretical curve. Initially the experimental lift-curve slope is about 85 per cent. of the theoretical value of 4π. As the deflection increases, the agreement worsens, but a C_L of 5.5 is reached for a flap

†If Q is the total quantity sucked per second. $C_Q = (Q/Ucs)$.

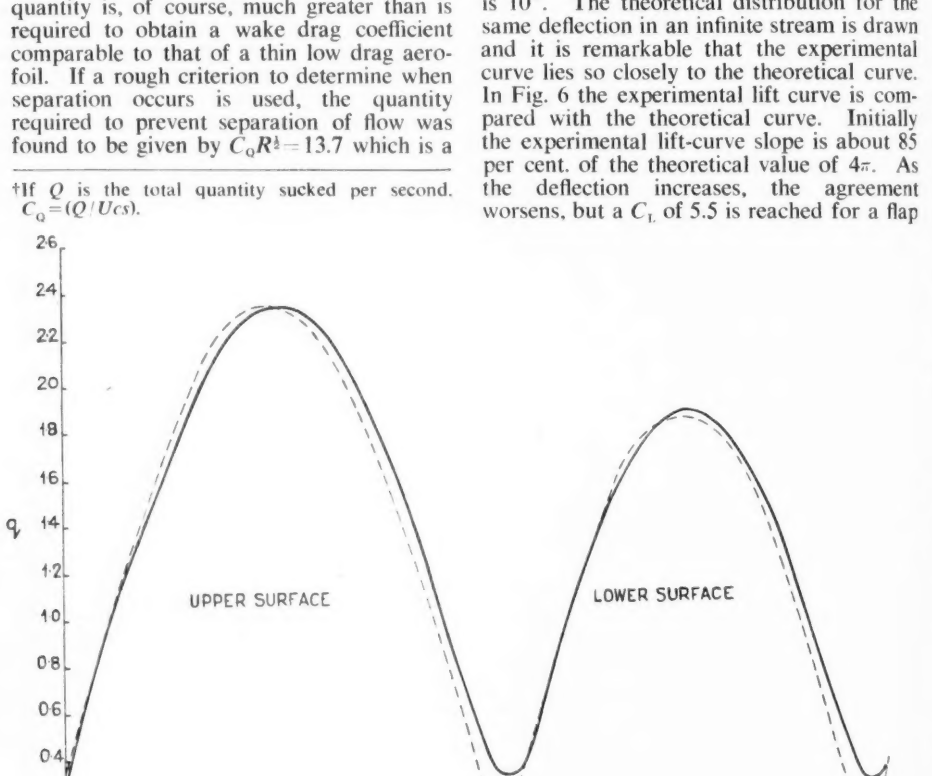


Fig. 5.

deflection of about 40°. The effect of the tunnel interference or of the shape and size of the flap at large deflections, remains to be investigated.

It is clear from this experiment that the flap does, in fact, produce circulation as predicted. A further experiment is being made on T.F.A. IV, an aerofoil similar to, but thicker than, T.F.A. V shown in Fig. 3.

4. PRACTICAL CONSIDERATIONS.

Although it is not the purpose of this paper to consider applications of the flap, a few observations on the practical aspects of its use are not amiss.

Although the principle is valid for any thickness of aerofoil it is probably true that the greater the trailing edge radius of curvature the better and therefore, that the flap is particularly suitable for aerofoils of large thickness. This in turn, indicates a low speed (as speeds go, nowadays) for fear of compressibility troubles. Considering the very large C_L range obtainable on such an aerofoil of, say, 50 per cent. thickness it is natural to think of a slow aircraft designed for very heavy loads at a cruising C_L of 1 or more.

The problem which is common to all applications of continuous suction and which must be thoroughly investigated, is the construction and maintenance of a suitable porous surface for full-size aircraft. The surface must satisfy the porosity requirements of §1, the loss of head through it should be as low as possible and it should not easily become clogged. Its weight should be small, but it must withstand and transmit aerodynamic pressures. These problems are not at all easy, but they must be solved before a full-scale aircraft can be built incorporating continuous suction in any of its several applications. Fundamental principles of various types of boundary-layer control have now been firmly established in experiment, and it is now necessary that detailed work be undertaken on these practical problems.

In thinking about the possibilities of obtaining high C_L's at zero incidence, it is natural to enquire whether it is not possible to obtain a very high C_L by more ordinary means. It may not be entirely out of place, therefore, to include in this paper Fig. 7 which shows C.V.A. II. This is a very thick aerofoil designed to have a constant velocity of 2.63 over AB and a constant velocity of .38 over ACDB, at a C_L of 6.6 and at zero incidence. For this aerofoil $C_M = 0$. Boundary layer suction must be applied at a slot near B to prevent separation. It may well be that some such high-lift aerofoil as C.V.A. II has a useful application.

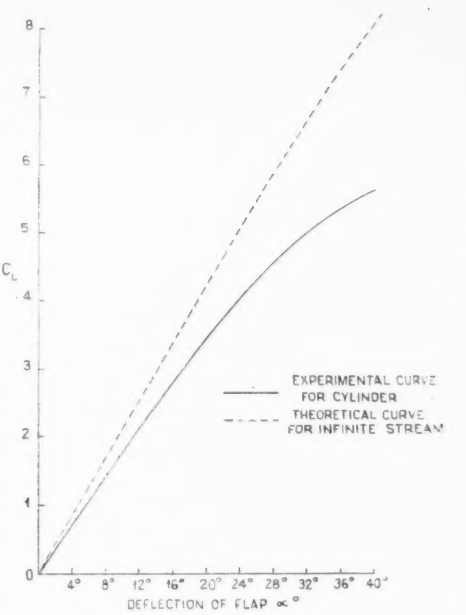


Fig. 6.

CONCLUDING REMARKS.

We have seen that it is possible to produce circulation about a body in a uniform stream independently of the incidence. Although the only necessary restriction on the shape of the body is that it must be well rounded, especially near the trailing edge, nevertheless in the application to aerofoils it is advantageous to design the aerofoil to have certain properties. The advantages which may be obtained by using an aerofoil fitted with the flap, instead of an ordinary aerofoil, may be summarised as follows:—

(i) It is possible to fly with the aeroplane in a constant attitude and, in particular, with the aerofoils at zero incidence.

(ii) The usual combination of flaps and ailerons may be unnecessary, since not only are high lift coefficients possible but also the lift of the two main planes may be varied independently.

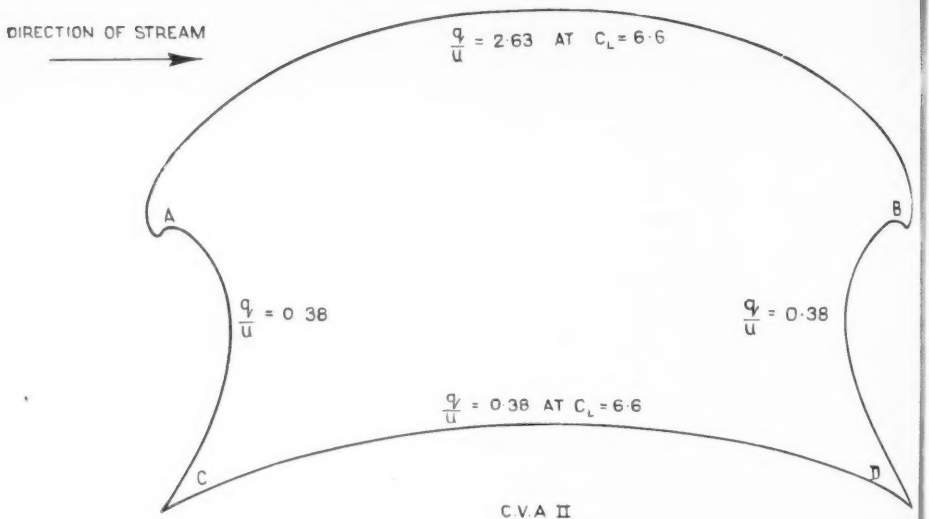


Fig. 7.

(iii) If very high C_L's are required, the usual separation of flow near the leading edge may be avoided by decreasing the incidence as the lift increases.

(iv) By virtue of (ii) and (iii), high incidences at landing, which are now often an embarrassment, are avoided.

(v) By correct design, laminar flow can be achieved over a large part of the aerofoil's surface.

(vi) A very large C_L range can be obtained, which is approximately double that of ordinary low-drag aerofoils of similar thickness.

(vii) The centre of pressure is constant for all C_L's at a fixed incidence and is close to the mid-chord point for zero incidence.

(viii) The moment coefficient is independent of C_L for a fixed incidence, and is always zero for a symmetrical aerofoil at zero incidence.

(ix) A very low maximum velocity may be obtained, thus ensuring a high critical Mach number.

(x) Doubly symmetric aerofoils are recommended for use, which also have the advantage of simple construction.

(xi) If the flap is wholly retracted there can be no change in circulation and thus gusts can be encountered with greater impunity.

(xii) The forces on the flap in steady flight are zero.

Experimental work has been done which fulfils to a great extent theoretical predictions and it seems, therefore, that provided some development work is done as suggested in §4, flight tests could profitably be made to demonstrate on the full-scale the possibilities of the flap.

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2. B. Thwaites: On the Design of Aerofoils for which the Lift is Independent of the Incidence. A.R.C. 10294 (January 1947).

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THE KINEMATICS OF UNDERCARRIAGE RETRACTION

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1. INTRODUCTION.

EACH time a new undercarriage design is laid down by an aeroplane or undercarriage designer, the geometry of the undercarriage retraction system has to be investigated. This often involves a review of known solutions and since the designer cannot be expected to remember all these known solutions, the following notes have been prepared to put on record most of, and possibly all, the known solutions.

2. FUNDAMENTAL RETRACTION MECHANISMS.

The basic linkage from which nearly all solutions are derived is the well-known four-bar linkage, as illustrated in Fig. 1. Links A and C rotate, link B is "floating," while the airframe forms the fourth link.

Figure 2 is the classic solution where the undercarriage leg is the rotating link A, the links B and C forming an articulated radius rod or folding stay. They may obviously fold either way.

Figure 3 is another type where the undercarriage leg is the floating link B and therefore the wheel does not retract along an arc. In fact, it can be made to retract almost vertically but in a direction away from the two attachment points. In this case the link C is a simple strut or guide rod, or bar. Landing loads tend to misalign the links A and B and therefore these loads tend to collapse the linkage.

Figure 4 is a similar linkage to Fig. 3, except that the link A hinges away from the others and the wheel comes up between the two attachment points.

Figure 5 shows a particular case of Fig. 3, where the link A is of infinite length and therefore the upper attachment point of the leg moves along a slot. Strictly, this need not be straight. Drag loads may tend to move the upper pin along the slot.

Figure 6 is a similar linkage equivalent to a particular case of Fig. 4.

Figure 7 is a particular case of Fig. 2 with the link C of infinite length and therefore the end of link B moves along a slot.

Figure 8 is similar to Fig. 7, except that the wheel is retracted the other way.

Figure 9 is a variation of the slider crank mechanism, commonly known as the oscillating cylinder mechanism. The end of the leg member slides down the radius link as the latter rotates, but landing drag loads tend to collapse the linkage.

Figure 10 is similar to Fig. 9 but with the sliding action down the leg. This is obviously superior to the earlier one since landing loads (and as drawn, retracted loads) are normal to the radius link.

3. PRACTICAL GEOMETRIES.

3.1. BASED ON FIG. 2.

Figures 11, 12, 13 and 14 are straightforward variations of the common type. Fig. 15 uses a self-breaking strut (para. 10). Figs. 16, 17 and 18 have the jack operating directly on the undercarriage, a small moment arm being provided to break the radius rod, directly in the cases of Fig. 17 and 18 and through a small linkage in the case of Fig. 16 which, however, requires an extra attachment point.

Figure 19 is a further variation where the radius rod links B and C overlap. As in Fig. 17, the jack operates on the undercarriage proper and a small offset at the other attachment of the jack breaks the latter. It will be noted that the radius link C rises first and then falls and that the two links B and C are in alignment in both up and down positions—an unusual feature.

3.2. BASED ON FIG. 3.

Figures 20 and 21 are straightforward variations of the basic type shown in Fig. 3;

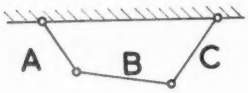
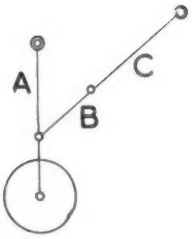


FIG 1.



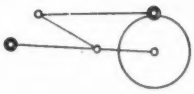
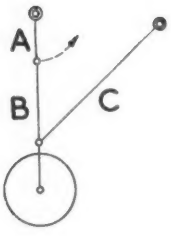


FIG 2.



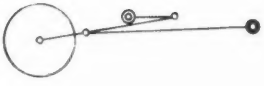
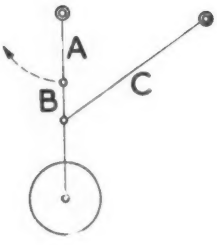


FIG 3.



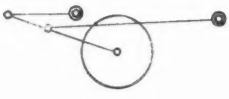
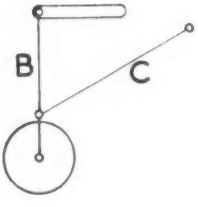


FIG 4.



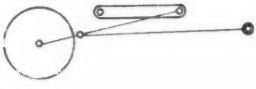


FIG 5.

that in Fig. 22 is possible but pointless, while Fig. 23 is a useful and interesting use of a self-breaking strut formed by the undercarriage members themselves. Fig. 44 is a further variation classified in para. 6 for convenience.

3.3. BASED ON FIG. 4.

Figures 24 and 25 are again straightforward, Fig. 26 having the jack carried on the structure as in Fig. 17, and Fig. 27 again being a self-breaking strut mechanism as Fig. 23.

3.4. BASED ON FIG. 5

Figures 28 and 29 illustrate obvious solutions.

3.5. BASED ON FIG. 6.

Figures 30 and 31 illustrate obvious solutions.

3.6. BASED ON FIG. 7 OR FIG. 8.

Figure 32 illustrates one method, the slot being arranged with a groove at the end in which the end of the stay sits, and which is undone automatically by the initial motion of the jack.

Figure 33 is similar, but applied to an undercarriage where the shock absorber is the central member and the lower link acts as a radius rod to guide the shock absorber unit and axle.

3.7. BASED ON FIG. 9.

Figures 34 and 35 show undercarriages retracted directly by the jack, which acts when extended as the stay member. Obviously the jack could push instead of pull.

3.8. BASED ON FIG. 10.

Figure 36 shows this interesting mechanism where the down and retracted loads do not come on the jack. Fig. 37 is similar but the jack is carried across the structure with suitable offsets at its ends to start the motion.

4. LINKAGES WHERE THE SHOCK ABSORBER MOVEMENT AFFECTS THE GEOMETRY.

Figure 38 is a common variation of Fig. 3 or 4, where the radius link C is attached to the axle and therefore moves over a slight arc as the oleo deflects. This eliminates much of the bending loads on the shock absorber.

Figure 39 is similar, except that the wheel (and possibly its swivel mounting if it is castorable) is mounted on an extension of the guide rod C.

Figure 40 is a particular variation where the wheel mounting only retracts with respect to a deformable triangular frame consisting of the oleo and a radius member.

Figure 33 also comes under this general heading.

5. MULTI-LINK MECHANISMS.

While, obviously, many multi-link mechanisms can be devised, such complications are rarely justified.

Figure 41 illustrates one known mechanism of excessive complexity.

Figure 42 shows a method of applying a jack through a second folding radius rod.

6. DEFORMABLE QUADRILATERAL MECHANISMS.

There is a special family of mechanisms where the shock absorber forms part of a quadrilateral, which deforms slightly during taxying and is completely deformed during retraction.

Figure 43 illustrates the geometry; the shock absorber is placed diagonally across a quadrilateral linkage which distorts during taxying. The whole is swung out of the way by any known means for retraction. The same object can be achieved by swinging the whole quadrilateral for retraction without actually deforming it.

Figure 44 appears to be similar, but is strictly a variation of the type in Fig. 3, the link A being approximately parallel to C.

7. RETRACTION INVOLVING MOTION IN TWO PLANES.

Numerous minor variations of known geometries can exist when the motion is not in a simple plane, as for example, when the radius rod is not in the leg retraction plane. Those illustrated in Figs. 45, 46 and 47 may be of particular interest.

Figure 45 shows a geometry of the Fig. 2 type, where the link C moves in a different plane to the undercarriage A.

Figure 46 shows one of the Fig. 3 type, where the links A and C again move in different planes.

Figure 47 shows a complicated solution to the problem of sideways retraction when the motion is not in a simple plane. The same object can be achieved merely by the proper inclination of the retraction axis.

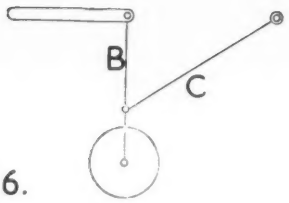
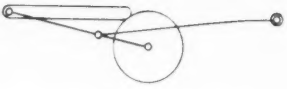


FIG 6.



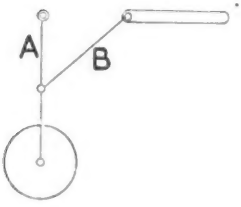
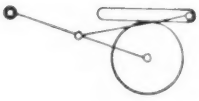


FIG 7.



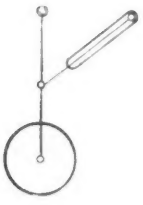


FIG 8.

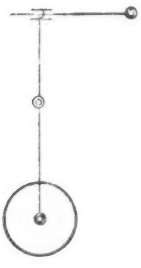


FIG 9.

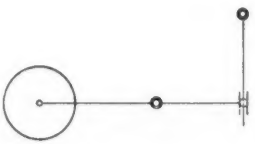
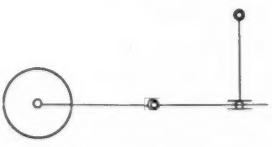


FIG 10.



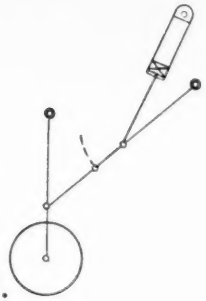


FIG 11.

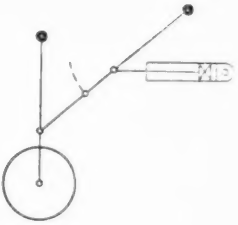
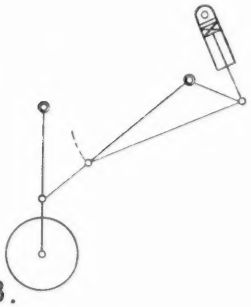


FIG 12.



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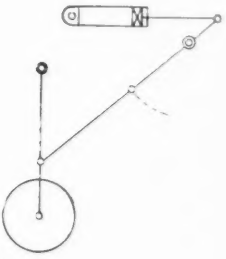

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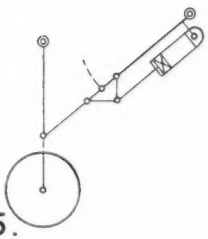

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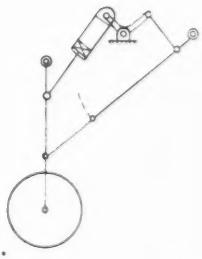

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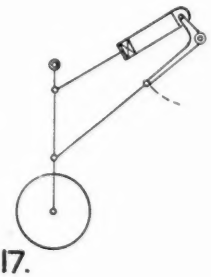

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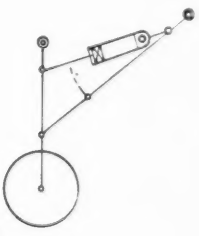

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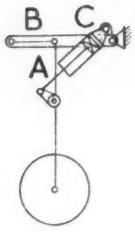

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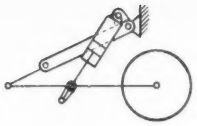

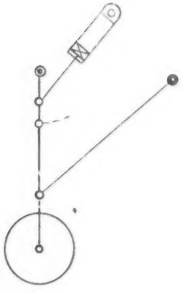

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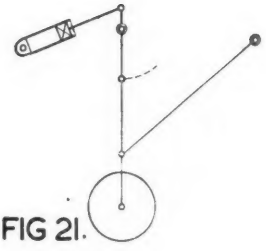

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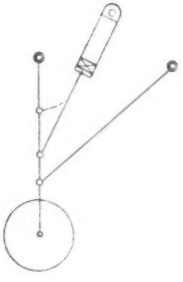

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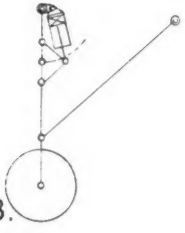

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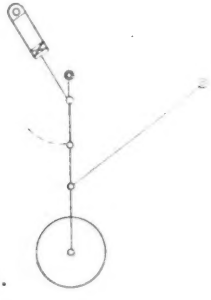

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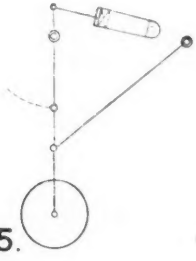

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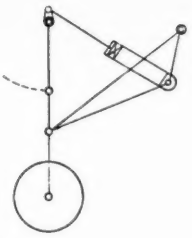

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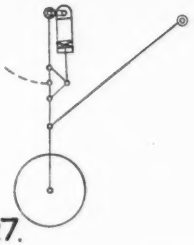

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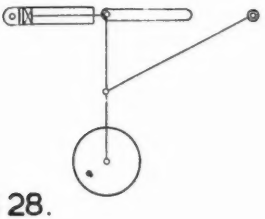

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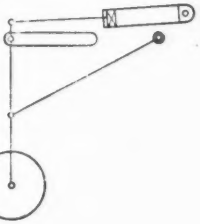

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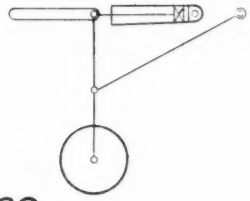

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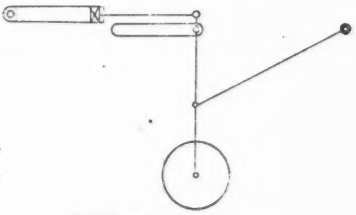

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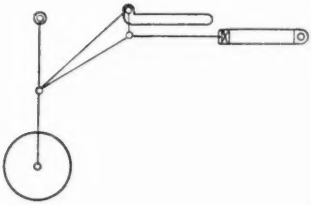

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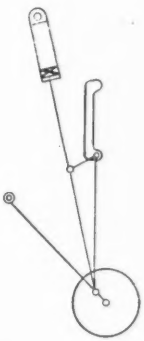

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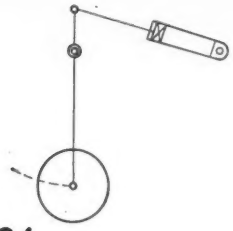

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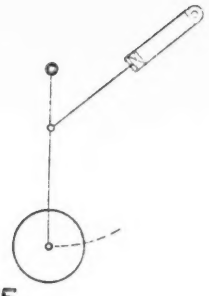
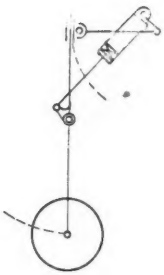


FIG 35.

FIG 36.



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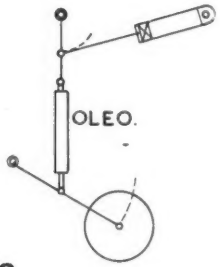

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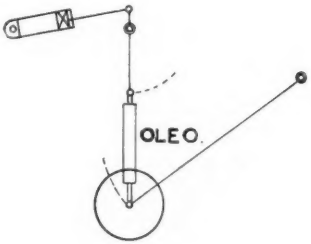

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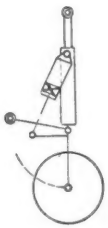

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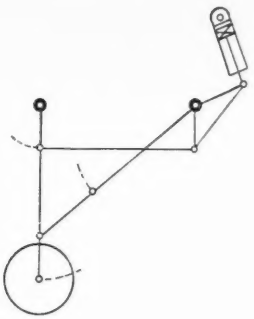

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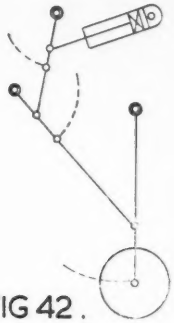

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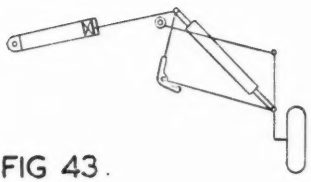

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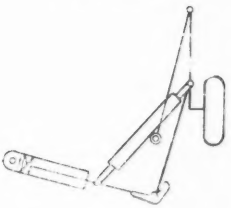

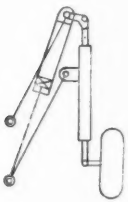

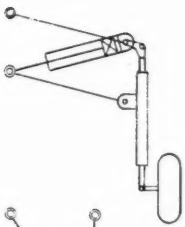

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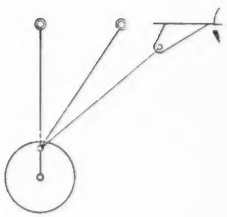

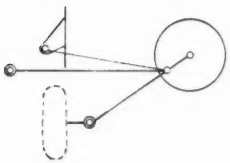

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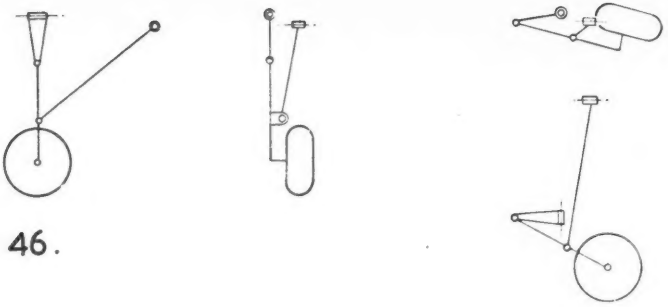

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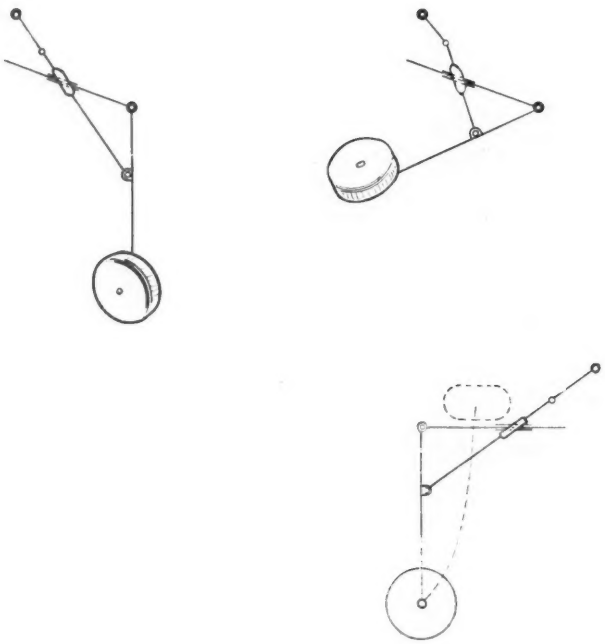

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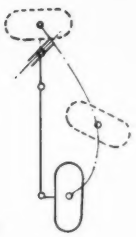

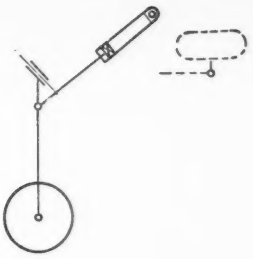

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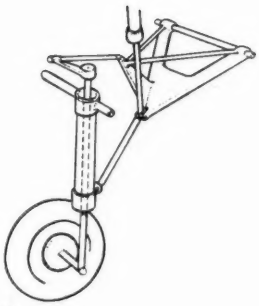

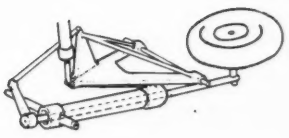

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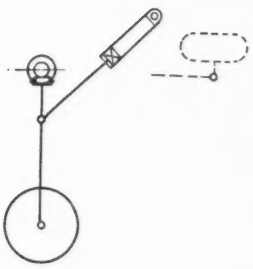

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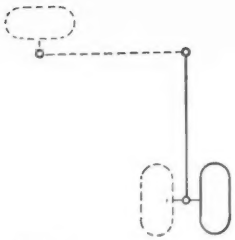

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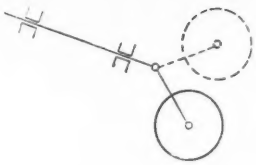

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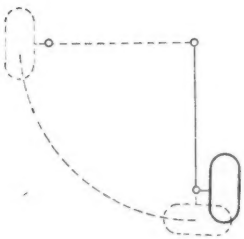

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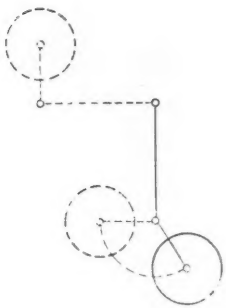
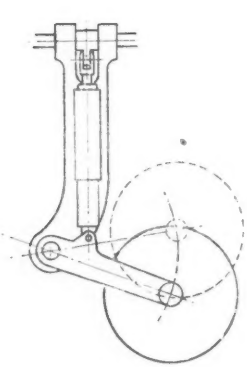


FIG 54.



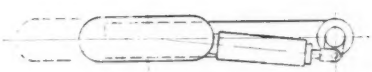


FIG 55.

8. HINGED WHEELS.

8.1. ROTATION ABOUT THE SHOCK ABSORBER AXIS.

Figure 48 shows a geometry where the retraction axis is skew and causes the wheel to retract along a helical path to lie flat in the wing.

Figure 49 illustrates a more convenient means of achieving the same object, the leg remaining in a fore and aft plane while a secondary linkage causes the wheel plane to rotate about the leg axis.

Figure 50 is equivalent to the last system, but uses bevel gears for the rotation.

An equivalent means is known for moving the wheel plane through 180° in the case of side retraction as shown in Fig. 51, while complete retraction by rotation of this type is known for tail wheels (Fig. 52).

8.2. HINGED AXLE.

Figure 53 illustrates a mechanism where the wheel axle swings round until it is in line with the leg axis prior to, or during, retraction.

Figure 54 shows a wheel fork which hinges specially prior to, or during, retraction so that the wheel is more conveniently disposed in the wing.

Multiple wheel undercarriages may have their wheels separate in some way or other to facilitate retraction.

9. CONTRACTING SHOCK ABSORBERS.

In certain cases it is advantageous to concontract or collapse the undercarriage, prior to retraction, to reduce the overall dimensions of the unit and thus facilitate stowage (units where the shock absorber *extends* during retraction, for clearance reasons, are also known).

Apart from purely hydraulic means of shortening the shock absorber, the system shown in Fig. 55 illustrates a convenient and simple mechanical linkage which will achieve the desired object, the contraction being progressive during retraction.

10. SELF-BREAKING STRUT LINKAGES.

The main types of such linkages are shown in Figs. 56 to 61; the action is self-explanatory.

FIG 56.

FIG 57.

FIG 58.

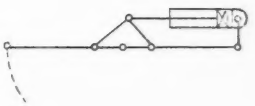


FIG 59.

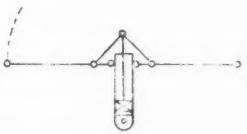


FIG 60.

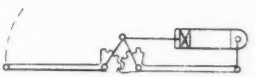


FIG 61.

CORRESPONDENCE

HIGH TEMPERATURE ALLOYS FOR GAS TURBINES

Sir William Griffiths presented a full and comprehensive review of the position with regard to high temperature alloys for gas turbines in his lecture (January 1948 JOURNAL), and one could only agree with all that had been said. Much credit was due to the metallurgists in evolving these high temperature materials, and their enthusiastic co-operation with the engineers had gone far in making the gas turbine a practical proposition.

Progress in gas turbine design would still require all the assistance and co-operation that the metallurgist could offer, if the present tendencies of design were to be met and thus enable British gas turbines to maintain the eminent position now held.

In his opinion it seemed doubtful whether short-time creep tests had any real value when endeavouring to assess the behaviour of a material to be used under creep conditions. For creep data to be of real service it had to be carried out over periods of time equal to, or preferably greater than, the length of life required in service. In the case of land installations this would cover a prohibitive space of time and it was to be hoped that the physicists would come to the rescue in finding an alternative solution for the assessment of creep.

He agreed that for the fatigue effect of the gas bending stresses in the rotor blades, a machine was required to make tests which would accurately reproduce service conditions. The Bristol Company had adapted an N.P.L. type of combined stress fatigue machine for the purpose of assessing the effect of reverse bending stresses superimposed on a static bending stress, at normal and elevated temperatures up to 800°C. utilising hollow test pieces. In addition, they had in operation a similar machine modified to apply reverse bending stresses to a turbine blade at temperatures up to 800°C., which was proving of value in enabling comparisons to be drawn showing the effect of alterations in production technique, changes in blade profile, and similar modifications.

It was intended to build in the future another machine for testing blades with reverse bending stresses, superimposed on a static tension and a static bending stress at elevated temperatures, which would enable service conditions to be simulated at critical points in a blade, although the frequencies would be considerably lower. Another apparatus contemplated would give reverse bending stresses at full operational frequencies and temperatures.

He agreed that the damping capacity of the blade material was of small importance in relation to the mechanical damping of the fir-tree attachment, but it should be remembered that at running temperatures the rotor rim tended to close on the blade root attachment and under many conditions gripped it very tightly, thus greatly reducing the mechanical damping. It might be that variation of initial fit under cold conditions, combined with this effect, was a cause of isolated blade failures.

Referring to the physical properties of blade materials, it was agreed that from a stress point of view the lower the specific gravity the better. He would point out that, while the main loading was centrifugal in the case of some turbines, in other designs this loading was smaller and the fluctuating bending stresses arising from the gas loading predominated, resulting in fatigue properties taking precedence over creep. This was the tendency with turbines designed for long operating life, although the position was obviously affected by the relative creep and fatigue properties, at the relevant operating temperatures, of the material adopted.

He would emphasise that, in order to apply the results of the fatigue tests he had mentioned to the design and development of turbines in a rational and qualitative way, it was essential to develop a technique for measuring the amplitude and frequencies of the blade vibrations under running conditions. At present, therefore, the fatigue data could only be applied on a comparative basis.

He was prepared to agree that usually the nozzle guide vanes were not subjected to high stresses on Whittle type engines, but conditions could be vastly different in a multi-stage turbine. There, the stator blades could not be supported at both ends and might, in addition,

be called upon to support a large diaphragm subjected to an appreciable pressure differential. In these circumstances, stresses could assume large proportions and creep strength became of major importance.

F. M. Owner, Fellow.
Chief Engineer, Engine Division, The Bristol Aeroplane Co. Ltd.

He was gratified at the extent of the agreement with his remarks expressed by one so experienced in the subject as Mr. Owner.

He was interested in what Mr. Owner had said about the Bristol Company's use and development of machines measuring the effect of combined creep and fatigue stresses. The devising of a suitable testing equipment of this type would certainly assist in the more rapid development of alloys to meet increasingly severe service conditions.

He thanked Mr. Owner for pointing out that in some circumstances the stresses imposed on nozzle guide vanes were appreciable. He agreed that there were such cases, and in these the advisability of using the same alloy for moving and stationary blades was naturally worthy of consideration. Indeed, in some designs this was already being done.

Sir William Griffiths.

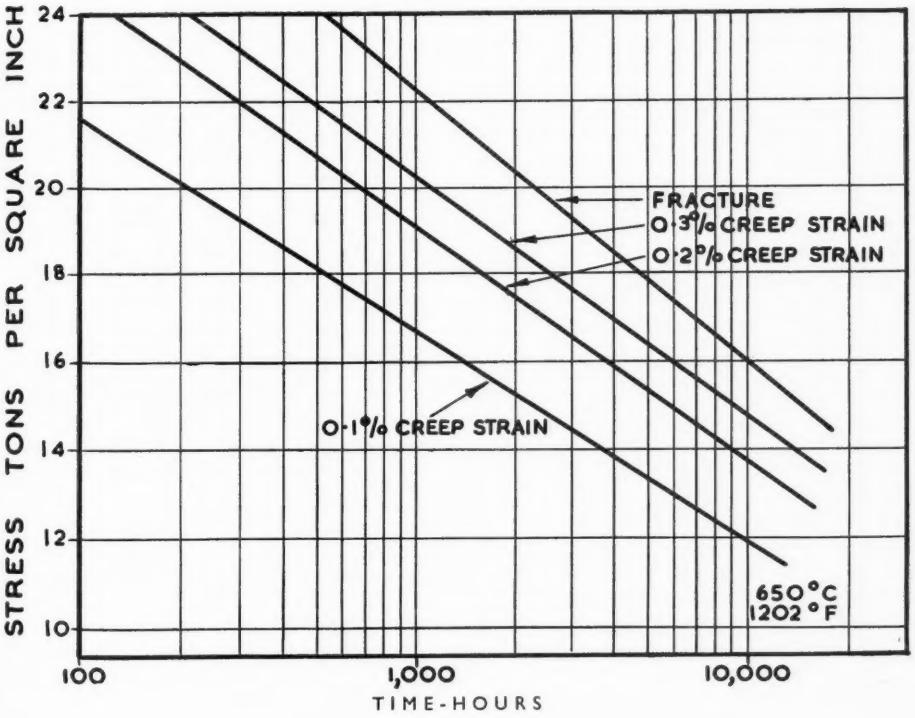


Fig. 7
Design data at one temperature (650° for the alloy "Nimonic 80")

This figure is a corrected version of Fig. 7 of Sir William Griffiths' paper "The Problems of High Temperature Alloys for Gas Turbines," published in the January 1948 Journal.

REVIEWS

Birds on the Wing. John Barlee. Collins, London, 1947. 12s. 6d. net.

There is only one comforting reflection about the modern craze for speed, that is that there is an upper limit. At present those who still believe that speed is the greatest asset the aeroplane has to sell are busy beating the speed of sound. That safely behind them, one expects in succession a series of higher and higher speeds to be attained. The comforting reflection, however, remains, that the speed of light can only be beaten when the ultimate end of all things has arrived.

Yet, with such a comforting reflection there will still remain, as long as the present general design of aircraft dominates, the problem of take-off and landing at ever-increasing speed from ever-increasing aerodromes.

"Birds on the Wing" is a sobering book. Those who know assert that the evolution of the bird was a matter of many hundreds of thousands of years and that its present graceful landing and ease of flight were not obtained by Nature without the building of many prototypes. Perhaps the time element may have deterred aircraft designers from paying the proper amount of attention to the landing and take-off problem, but Nature has done so much that, despite the great difference in the Reynolds' numbers of Nature and of the aircraft designer, it might still be worth the latter's while to have another look at the bird.

Here are beautiful photographs, beautifully reproduced of birds in flight, and a text written so understandingly that one envies every minute the author spent preparing this book. His photographs of swans in flight, the tern attacking, the fulmar, the gannet and the gull, to name only a few, are a delight to the technical as well as the non-technical eye.

This is a book which anyone who flies an aeroplane should have, and anyone who designs an aeroplane must have.

Atomic Challenge. Winchester Publications Ltd., London, 1947. 8s. 6d. net.

"Atomic Challenge" is the publication of the B.B.C. "Atomic Week" broadcasts by Professor J. D. Cockcroft, M. L. Oliphant, P. M. S. Blackett, Group Captain G. L. Cheshire, Dr. J. Bronowski, Sir George Thomson, Captain Cyril Falls, Sir Henry Dale, Bertrand Russell and Henry Wallace. To it have been added the comments of a number of students of different nationalities.

The publishers have done well to put on permanent record the considered opinion of so many atomic experts, and of many who are not experts at all. There is the point of view of Miss Helga Wolpert, twenty-two year old student, of Russo-Polish descent. She is a fatalist: "I can suggest no concrete solution of the problems which it throws up. 'Desperate', indeed, but what can a fatalist do against so many people determined to commit mass suicide?"

"The human race has to choose between utter disaster and unexampled well-being—no middle course is any longer possible," says Bertrand Russell.

Professor Cockcroft is historically non-committal and Professor Oliphant follows suit, while Professor Blackett is hopefully peaceful. Group Captain Cheshire flew as British operational observer in the aircraft that droppped the first atomic bomb on Japan.

"If man persists in claiming atomic energy for himself and entrusts its custody to purely human wisdom, then I for one hold little brief for the future of civilisation."

And so on.

The outlook of man at the present time is one of fear—fear of an atomic war—fear of slave domination—fear almost indeed of living at all. And as long as man is afraid to live then he must surely die.

But why he should be afraid of himself and of his own creations, is something which has puzzled the reviewer for many years.

"Atomic Challenge" does not provide a solution to the puzzle.

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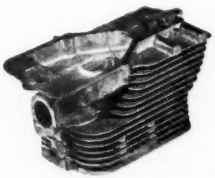

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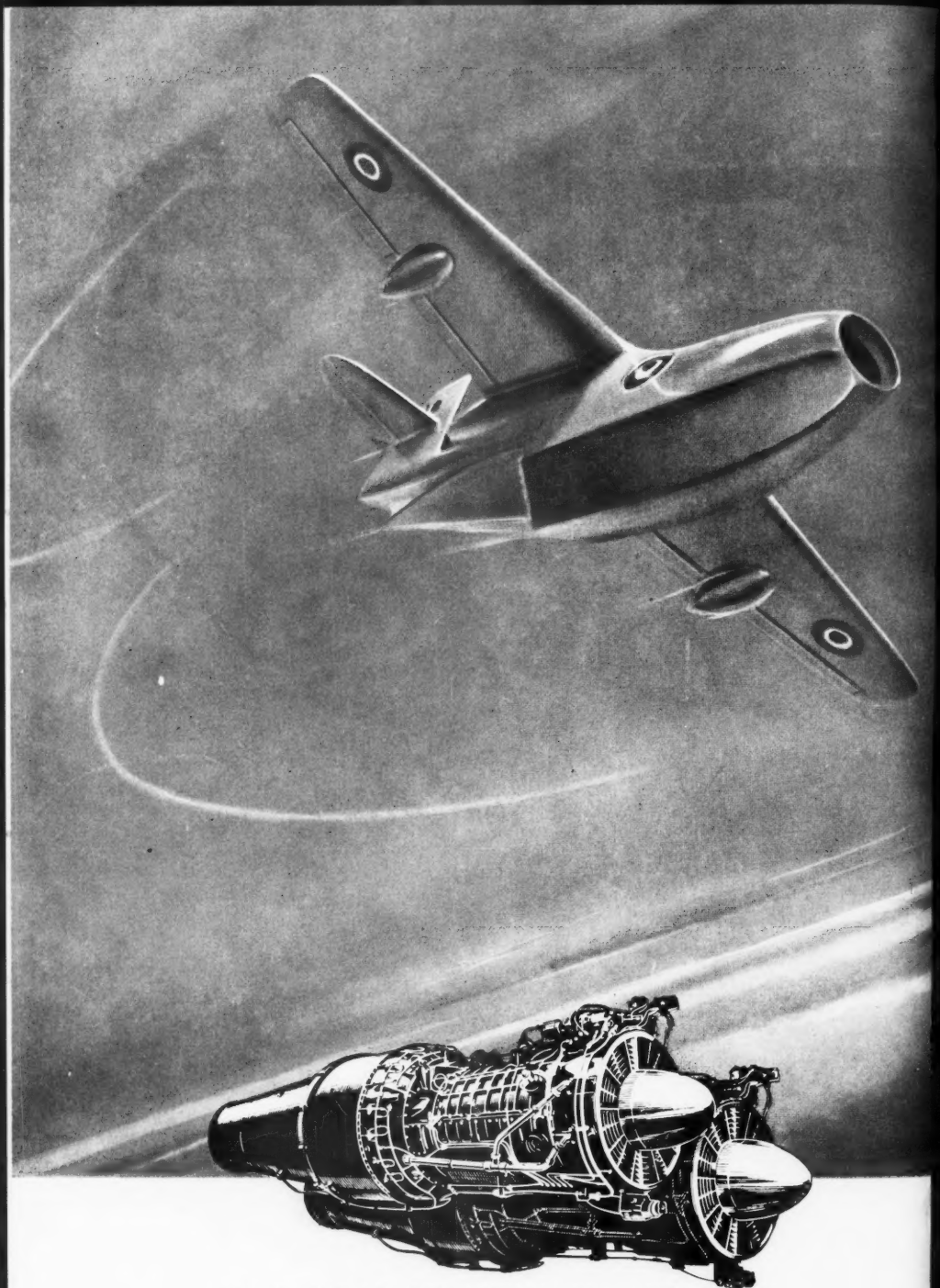

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